Circuit Court of the United States,

EASTERN DISTRICT OF PENNSYLVANIA.

IN EQUITY.

AMERICAN BELL TELEPHONE COMPANY ET AL.

v.

THE CLAY COMMERCIAL TELEPHONE COMPANY ET AL.

BILL OF COMPLAINT.

[FILED APRIL 24, 1884.]

To the Honorable the Judges of the Circuit Court of the United States within and for the Eastern District of Pennsylvania.

The American Bell Telephone Company, a corporation duly established under the laws of the Commonwealth of Massachusetts, and the Bell Telephone Company of Philadelphia, a corporation duly established under the laws of the State of Pennsylvania, bring this their bill of complaint against The Clay Commercial Telephone Company, a corporation organized under the laws of the State of New Jersey, and exercising its franchise within said judicial district, John C. Scott, James McMillan, George W. Bratton, Samuel P. Godwin, Alonzo P. Douglass, W. Harrison Godwin, Henry Clay, John J. Bailey, John Marston, Jr., Thomas C. Else, James McC. Creighton and Joseph Wright.

And thereupon your orators complain and say: —

1. On or about Feb. 14, 1876, Alexander Graham Bell, then of Salem, in the State of Massachusetts, being theretofore the original and first inventor of certain new and useful improvements in telegraphy, made application in due form of law to the Commis-

sioner of Patents of the United States, for the grant of a patent securing to him exclusive property in his said improvements, which had not been known or used by others in this country, nor patented or described in any printed publication in this or any foreign country, before his invention thereof, and which had not been in public use or on sale for more than two years prior to his said application.

Thereupon, after due proceedings in all respects according to the requisitions of the statutes in such case made and provided, Letters Patent of the United States, numbered 174,465, dated the seventh day of March, in the year 1876, signed by the Secretary of the Interior and countersigned by the Commissioner of Patents, were issued under the seal of the Patent Office, and delivered unto the said Alexander Graham Bell; whereby was granted to him, his heirs or assigns, for the term of seventeen years from the said date of the same, the exclusive right to make, use and vend the said invention throughout the United States and the Territories thereof, as will more fully appear by the said patent, or by a copy of the same duly certified from the records of the Patent Office, and in this court to be produced.

2. On or about Jan. 15, 1877, the same Alexander Graham Bell, being theretofore the original and first inventor of certain new and useful improvements in electric telephony, made application in due form of law to the Commissioner of Patents of the United States for the grant of a patent securing to him exclusive property in his said improvement, which had not been known or used by others in this country, nor patented or described in any printed publication in this or any foreign country, before his invention thereof, and which had not been in public use or on sale for more than two years prior to his said application.

Thereupon, after due proceedings in all respects according to the requisitions of the statutes in such case made and provided, Letters Patent of the United States, numbered 186,787, dated the thirtieth day of January, in the year 1877, signed by the Secretary of the Interior and countersigned by the Commissioner of Patents, were issued under the seal of the Patent Office, and delivered unto the said Alexander Graham Bell; whereby was granted to him, his heirs or

assigns, for the term of seventeen years from the said date of the same, the exclusive right to make, use and vend the said invention throughout the United States and the Territories thereof as will more fully appear by the said patent, or by a copy of the same, duly certified, from the records of the Patent Office, and in this court to be produced.

3. Afterwards, the said Alexander Graham Bell, by an instrument in writing, bearing date July , 1877, and recorded in the Patent Office, July 28, 1877 (Liber R^{21}, page 399, of Transfers of Patents), assigned unto Gardiner G. Hubbard, trustee, each of the Letters Patent aforesaid, numbered respectively 174,465 and 186,787. The said Gardiner G. Hubbard, trustee, on or about July 20, 1878, by an instrument in writing, bearing that date, and recorded in the Patent Office, Oct. 3, 1878 (Liber Y^{22}, page 460, of Transfers of Patents), assigned the said Letters Patent, and each of them, unto the Bell Telephone Company, a corporation established under the laws of the Commonwealth of Massachusetts. The said Bell Telephone Company afterwards, by an instrument in writing, bearing date June 22, 1880, and recorded in the Patent Office, June 24, 1880 (Liber I^{25}, page 282, of Transfers of Patents), granted and conveyed unto your orators, the American Bell Telephone Company, the exclusive right under the said Letters Patent, and each of them, to the whole of the United States except the State of Massachusetts; and by another instrument in writing, bearing date April 23, 1881, and recorded in the Patent Office, July 6, 1881 (Liber B^{27}, page 101, of Transfers of Patents), the said Bell Telephone Company granted and conveyed unto your orators, the American Bell Telephone Company, the exclusive right under the said Letters Patent, and each of them, to the State of Massachusetts. All of which will more fully appear by the said several written instruments, or by copies of the same, duly certified, from the records of the Patent Office, and in this court to be produced.

4. The sole right to manufacture electric speaking telephones under said patents thereby became, and still is, vested in the said American Bell Telephone Company; and the only right granted to, or possessed by, any persons other than the said American Bell Telephone Company under said patents has been, and is, the right to use

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telephones procured from said American Bell Telephone Company and its predecessors, upon payment of stated royalties under said two patents to the said American Bell Telephone Company.

That by license under the said American Bell Telephone Company, the Bell Telephone Company of Philadelphia, a corporation organized under the laws of the State of Pennsylvania, has acquired the sole and exclusive right to use telephones within a territory which includes all of the city and county of Philadelphia, the counties of Bucks, Chester, Delaware, and Montgomery in the State of Pennsylvania, and all of the counties of Mercer, Salem, Cape May, Cumberland, Atlantic, Gloucester, Camden, Burlington, and Ocean in the State of New Jersey, and all of the State of Delaware, and is now engaged in the business of supplying electric speaking telephones, and erecting telephone lines in said territory, which telephones it receives from the said American Bell Telephone Company, and for the use of which it pays a yearly license fee and royalty to the said American Bell Telephone Company, and receives a yearly license fee and royalty from its sub-licensees.

5. Electric speaking telephones had never been publicly known or used before the grant of said patent, No. 174,465. They were first publicly made known by said Bell, and were by him and his licensees first introduced into public use under the said patents, No. 174,465 and No. 186,787. After the grant of said patents, the inventions therein described and claimed, or substantial and material parts of the same, embodied in instruments known as Bell telephones, and in instruments known as Blake transmitters, were, before July, 1877, and January, 1879, respectively, introduced into general public use by the said Bell, the said Hubbard, trustee, and the said Bell Telephone Company. Since then many thousand persons have put the said inventions, so embodied, into daily use under the authority and license of your orators, the said American Bell Telephone Company, and their predecessors, and those holding rights or licenses under them, and have paid for such use of said inventions the amount fixed by the owners of said patents as a reasonable compensation therefor, such payments amounting in the aggregate to many thousands of dollars. Telephone exchanges under license from your orators, the American Bell Telephone Company, now exist in

more than one thousand towns and cities of the United States, and in every State thereof, and exist in substantially every city of the United States having more than 5,000 inhabitants, and in many smaller places; and all said exchanges use telephones licensed by your orators, the American Bell Telephone Company, and their predecessors, as owners of said patents to Bell, and pay royalty therefor to your said orators. The fact that said Bell was the original and first inventor of said inventions, and that the patents above named are good and valid patents, has been generally recognized and acknowledged by those who have used the inventions and by the public generally in all parts of the United States; and the claims of the said Bell and your orators, the American Bell Telephone Company, and their said predecessors, to the exclusive right to the said inventions under said patents, have been generally acknowledged and acquiesced in. From time to time several persons have attempted to make, sell and use telephones, or parts thereof, embracing said inventions, but in such cases your orators, the American Bell Telephone Company, or their said predecessors, have immediately, upon hearing of such acts or attempts, notified such persons to desist therefrom, and such persons have generally, upon receiving such notice, complied therewith, and acquiesced in and recognized as valid the claims of your orators, the American Bell Telephone Company, and their predecessors, under said patents; and said Bell, and those deriving title from him as aforesaid, have always asserted and maintained, and, but for the wrongful acts of the defendants, would have hitherto almost universally enjoyed the sole and exclusive right to practise said inventions. Your orators, the American Bell Telephone Company, and their predecessors have never acquiesced in any infringement of their exclusive rights, but whenever any such infringement has come to their knowledge, and been continued after notice to desist, they have commenced action to restrain the same; and the said exclusive rights of your orators are of great value to them.

6. The transmission of articulate speech, telegraphically, according to the method invented by the said Bell and patented to him as aforesaid, constituted an entirely new industrial art; and the manufacture and introduction into use of instruments and apparatus for

such purpose is an industry which was originally created under the said patents to Bell, and which has been developed wholly and solely by the owners of the said patents and their licensees.

The introduction of the electric speaking telephone into use and its application to the various requirements of users, and the construction and adaptation of means and appliances for enabling it to supply the wants of the community, have involved great labor and expense on the part of your orators, their predecessors and licensees, and have necessitated the acquirement by them of skill, knowledge and experience, not before possessed or exercised by any one.

There are now in use more than 300,000 electric speaking telephones, licensed by and paying royalty to your orators, the American Bell Telephone Company. The owners of said patents to Bell, and those who now are, or heretofore have been, licensed by them, have devoted much time and attention, and large sums of money to the development of the telephone and the introduction thereof into extensive use, and to the proper construction of the most suitable telephone lines and systems and telephonic appliances, and have constructed many thousand miles of telephone lines for use with telephones owned by your orators, the American Bell Telephone Company, and licensed by them for such use, and nothing which the defendants, or either, or any of them, have done, has contributed in any substantial way to the development of the telephone, or the introduction thereof into use.

For all this labor and expenditure which the introduction of the telephone into use, and the application of the same to the various requirements of users has involved, as well as for the intrinsic value of the inventions of Bell embraced in the telephone itself, your orators can obtain adequate compensation only by the undisturbed enjoyment of the exclusive rights granted by the said patents. Persons attempting to make, sell, use or furnish for use electric speaking telephones without license from your orators, not only violate the exclusive rights so granted by the said patents, but avail themselves of the knowledge and experience which have been gained by the long-continued labors, trials, efforts and expenditures of your orators, their predecessors and licensees, in the development of the telephone, and the introduction thereof into use. Such unauthorized

manufacturer, vendor or user of telephones, if unrestrained, would thus have the power either to make greater profits therefrom than your orators or their licensees could otherwise make, or to compel your orators and their licensees, by unlawful competition, to reduce the prices hitherto established by them as just and reasonable compensation for what they have done, acquired, and paid in the premises.

7. From time to time, sundry persons have undertaken to manufacture and use electric speaking telephones, and to infringe the said patents. The owners of said patents have requested them to stop, and for the most part they have, upon being so notified, desisted from such infringement. Your orators, the American Bell Telephone Company, and their predecessors, owners of said patents to Bell, have brought suit in the courts of the United States and obtained injunctions and decrees against such infringers; and among the suits so brought and which have resulted in injunctions or decrees are the following: —

8. The said exclusive rights of said Bell, and your orators, the American Bell Telephone Company, and their predecessors, as his assigns and grantees, have never been openly or publicly violated, to any considerable extent, except at one time and in the year 1878, by the Western Union Telegraph Company, and by the Gold and Stock Telegraph Company, and by the American Speaking Telephone Company, said three corporations having associated themselves together for that purpose. The said Bell Telephone Company brought their bill in equity in the Circuit Court of the United States for the District of Massachusetts, against Peter A. Dowd, an agent of said associated companies, engaged in the business of using their infringing telephones, and in said suit complained of the defendant that he had infringed the fifth claim of said patent No. 174,465; and also complained that he had infringed the third, sixth, seventh and eighth claims of said patent No. 186,787. The said associated corporations assumed the defence of said suit, and employed in said defence their counsel and experts, learned in the law and skilled in the art. In said suit, evidence was taken and completed by the complainants in-chief, and by the defendant in defence, and by the complainants in reply; and thereupon, upon consideration of said proofs, and the opinions of their professional advisers, the defendant and

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said corporations became satisfied that said Bell was the true, original and first inventor of the electric speaking telephone, and the inventions covered by said patents; whereupon they submitted to the said claims of the complainants, and agreed to desist from further infringements, and have since desisted from further infringements, and placed and caused to be placed all telephones within their power or control under license under said patents to Bell, and paid, or caused to be paid, the usual and customary yearly royalties therefor, habitually charged by the assigns of said Bell to other parties for like uses; and agreed that they would not thereafter make electric speaking telephones, and would not thereafter use electric speaking telephones, except such as should be made and furnished to them by your orators or the assigns of said Bell, and under license under said patents to Bell, and that for the use of the same they would pay not less than the usual and accustomed royalties, from time to time charged to others by your orators; and in accordance with the said advice of counsel of said telegraph companies a final decree was thereafter made and entered in said suit for the complainants, with the consent of the defendant Dowd, and, in and by said decree, the said two patents to Bell were adjudged and declared to be valid patents, and the defendant was perpetually enjoined from infringing the same.

9. In the year 1880, the People's Telephone Company, a corporation organized under the laws of the State of New York, and Frank A. Klemm, Joseph Loth, Julius Bien, Marcus Marx, Auguste H. Girard, John N. Goodwin, Ernest Marx, Edgar W. Chellis, Richard C. McCormick, Henry D. Cooke, Jr., Max L. Gutmann, Moritz Loth and Simon Wolfe, did make, sell and use, and threaten to make, sell and use certain electric speaking telephones, some of which were known as the "Klemm" telephones, and some of which were known as the "Tisdel" telephones. Said defendants owned the alleged inventions of Frank A. Klemm and of Abner G. Tisdel, and of Daniel Drawbaugh, relating to electric speaking telephones; and thereupon your orators, the American Bell Telephone Company, and the Metropolitan Telephone and Telegraph Company, licensees of said American Bell Telephone Company, did, in the United States Circuit Court for the Southern District of New York, file a bill in equity against all of said parties, complaining that such acts done and

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threatened infringed the rights secured to the said orators by the said two patents to Bell, No. 174,465 and No. 186,787; and did also move for an injunction therein, *pendente lite*. Said motion came on to be heard in said Court, before the Honorable Samuel Blatchford, Circuit Judge, on the nineteenth day of November, 1880, on affidavits and proofs filed by the respective parties, and was argued by counsel; to wit, by Chauncey Smith and James J. Storrow, Esquires, for the complainants, and by George Harding, Esq., for the defendants; and, upon consideration of the proofs and arguments, the Court did order an injunction as prayed for, restraining the defendants from infringing the said two patents of your orators, No. 174,465 and No. 186,787. Such injunction issued accordingly on the twenty-second day of November, 1880; and your orators refer to a copy of the record in said suit, to be produced, and pray that the same may be made part hereof.

10. In the year 1880, the Eaton Telephone Company, and its associates, did infringe said patents in New York by making and selling an electric speaking telephone apparatus, composed of a magneto telephonic receiver of a form and style called by them the Eaton Magneto Telephone, and of a microphone battery telephonic transmitter, with carbon contacts; and did infringe said Bell patents in Massachusetts by selling the same to others by their employé, Albert L. Spencer; whereupon your orators, the American Bell Telephone Company, brought suit against said Eaton Telephone Company and others in the United States Circuit Court for the Southern District of New York, and against said Spencer in the District of Massachusetts, complaining that said defendants had thereby infringed the fifth claim of patent No. 174,465, and the fifth, sixth, and eighth claims of patent No. 186,787; and said Eaton Telephone Company and their associates defended said two suits, and employed in that behalf counsel learned in the law and experts, whereupon a preliminary injunction was issued in both suits. Afterwards said suits were prepared for final hearing, and the defendants denied the validity of said patents, and denied that the use of a microphone telephonic transmitter with carbon contacts infringed said p tents; and in support of such denial, and of other allegations in their answer, they introduced evidence; and among other evidence they intro-

duced the depositions of Elisha Gray, and of William M. Goodridge, and of Henry Morton and of Edward S. Renwick; and the same evidence on both sides was introduced in said two suits. Said suit in Massachusetts came on to be heard on final hearing before his Honor, Judge Lowell, Circuit Judge at Boston, and was argued by counsel; and was, on June 27, 1881, decided by the Court in favor of the complainants; and in its said decision, the Court, among other things, expressly held and decided that all the said claims of said patents sued on, were good and valid claims, and that said patents were valid patents, and that the use of the kind of speaking telephone transmitter, commonly known as a microphone transmitter, with carbon contacts, whereby the resistance of a battery circuit was varied by variations of pressure due to vibrations imparted to one electrode by sound waves, infringed said fifth claim of the patent to Bell, No. 174,465. Your orators crave leave to refer to the record of said case, and to the opinion of said Court therein pronounced, and ask that the same may be made and deemed to be part hereof.

Your orators also refer to the following: —

11. A suit in the United States Circuit Court for the District of Massachusetts, brought in 1878 against Addison D. Hard, electrician, which resulted in a preliminary injunction; afterwards, the said defendant made and exposed for sale some parts of electric speaking telephones, to the end that the purchasers thereof should complete and use the same; whereupon, after hearing, he was adjudged guilty of contempt, and ordered to pay a sum of money into Court, which sum was afterwards ordered to be paid, and was paid to the complainants, the Bell Telephone Company. Said suit has been terminated by a final decree for the complainants.

12. A suit in the same Court against Jerome C. Redding, electrician, in 1878, which resulted in a preliminary injunction, and a final decree for the complainants.

13. A suit in 1878, in the United States Circuit Court for the Southern District of New York, against Jesse H. Bunnell, manufacturing electrician, who appeared by counsel; which resulted in an injunction and a final decree for the complainants.

14. A suit in 1878 in the United States Circuit Court for the Southern District of Ohio, against Charles E. & W. H. Jones, who

appeared by counsel; which resulted in a final decree, declaring the validity of said patents, and enjoining further infringement thereof.

15. A suit in 1880, in the United States Circuit Court for the Southern District of New York, against Pearce & Jones, manufacturing electricians, who appeared by counsel; which resulted in a final decree declaring the validity of said patents, and enjoining further infringement thereof.

16. A suit in 1880, in the same court, against J. L. Lazelle, a manufacturer of electrical apparatus, complaining that he infringed said patents by making and selling a form of magneto telephones, sometimes called "Lazelle" telephones, and a form of microphone telephonic transmitters, sometimes called the "Little Gem" transmitters. This suit resulted in a preliminary injunction, and a final decree and perpetual injunction.

17. A suit in 1881, in the United States Circuit Court for the Northern District of Illinois, against Edward E. Harbert and Harbert & Co., manufacturing electricians, in which said Harbert appeared in person; which, after hearing, resulted in a preliminary injunction, and a final decree and perpetual injunction.

18. A suit in 1881, in the same court, against The Foster Magnet Telephone Company, Gay W. Foster and others, in which the defendants appeared by counsel, and which resulted in a preliminary injunction, and a final decree establishing the validity of said patents, and perpetually enjoining all further infringement thereof.

19. A suit in 1881, in the United States Circuit Court for the Southern District of New York, against Henry Thau, manufacturer of electrical apparatus, in which the defendant appeared by attorney; which resulted in a final decree and perpetual injunction.

20. In 1881, a suit was brought on said two patents to Bell, in the United States Circuit Court for the Southern District of New York, against one Albert Craney, and others, who used at West Point, on premises belonging to the Military Academy of the United States, a certain telephone apparatus, known as the "Eccard Telephone," which is substantially described in United States patent, No. 214,029, granted to Adolph Eccard, April 8, 1879. The said defendants, by the procurement and at the expense of said Eccard and his associates, who were also made defendants, appeared by [illegible], Gregan, and the

their counsel, John H. Latrobe and Causten Browne, Esquires, and filed an answer, and thereupon evidence was taken for complainants.

The defendants failed to take evidence, and gave up the contest; and upon the day of hearing, the Court ordered a final decree against them, and, thereupon, a final decree and perpetual injunction issued against them.

21. In the year 1881, Amos E. Dolbear and others infringed the said patent to Bell, No. 174,465 by the construction and use of certain telephone apparatus, which consisted of a microphone transmitter and a condenser receiver.

A bill in equity was thereupon filed against said infringers in the United States Circuit Court for the District of Massachusetts.

A motion for preliminary injunction was made therein, which was heard before Justice Gray and Judge Lowell, and, after a full and elaborate hearing, the injunction was by them ordered and was accompanied by an opinion, a copy of which the complainants will produce, and to which they crave leave to refer.

Subsequently the pleadings were completed in said suit, and issue was joined thereon, and proofs were taken by the respective parties, and the cause proceeded to final hearing before his Honor, Judge Lowell, and was argued by counsel; and on August 25, 1883, the Court decided the case in favor of the complainants, sustaining the validity of the said patent to Bell, No. 174,465, and holding that the defendants had infringed upon the fifth claim thereof, by the use of the apparatus complained of. Your orators crave leave to refer to the record in said case, and to the opinion and final decree of the Court therein, and ask that the same may be deemed to be a part hereof.

22. In the year 1882, the People's Telephone and Telegraph Company infringed the said two Bell patents by making speaking telephones, and by causing them to be sold and used in the District of New Jersey by John J. Ghegan. Suit was brought in the United States Circuit Court for said district against the said Ghegan, and motion for preliminary injunction was made therein. Affidavits having been taken and filed, the cause was heard, George Harding, A. Q. Keasbey, and H. D. Donnelly, Esquires, appearing to contest the case for the defendants; and thereupon, after hearing, the Court made a decree and granted an injunction. Afterwards said cause

proceeded to final hearing, and the defendant and the said People's Telephone and Telegraph Company gave up further defence, and a final decree and a perpetual injunction were ordered and issued against the defendants.

The like proceedings were had, and the like final decree and perpetual injunction issued from the same court against Andrew Albright, a licensee of said People's Telephone and Telegraph Company. And thereafter, in the United States Circuit Court for the Southern District of New York, the complainants brought their bill in equity against said People's Telephone and Telegraph Company, and upon motion the Court granted an injunction therein, ordering the said company to desist from further infringement of the said two patents to Bell.

23. All said injunctions and decrees still remain in full force and effect, and the defendants named have, so far as the complainants are informed, entirely ceased to use or sell electric speaking telephones.

24. The apparatus used by the above-named defendants, the People's Telephone Company, the Eaton Telephone Company, and Spencer, Pearce & Jones, Lazelle, Harbert, Thau, Amos E. Dolbear *et al.*, Ghegan, and the People's Telephone and Telegraph Company, consisted of an electric speaking telephone apparatus, which employed what is known as a microphone, or carbon transmitter, as the transmitting member, and which employed what is known as a magneto telephone as the receiving member, except in the case of said Dolbear, who employed what is known as a condenser receiver for the receiving member. An apparatus consisting of a carbon transmitter and magneto receiver, as aforesaid, is substantially the apparatus employed by the defendants herein; and, in and by the said decrees in said cases, it was expressly decided and adjudged that a speaking telephone apparatus which employed the said instruments, infringed the claims of the said patents, although said instruments differed in their construction from that specifically shown in the drawings of the said patents to Bell.

Furthermore, the specific instruments used by the defendants in the said suits against The People's Telephone Company, the Eaton Telephone Company, and Spencer, Dolbear *et al.*, Ghegan, and the

People's Telephone and Telegraph Company, exhibit changes and differences from those specifically described in the patent to Bell, which changes and differences were themselves the subject of patents, and some of which are owned by the said respective defendants.

25. And your orators show that the telephones made by your said orators, the American Bell Telephone Company, and the infringing telephones of the defendants, are small instruments, and easily concealed, and easily used in private, and easily transferred from one person to another, so that it is generally extremely difficult for your orators to detect all instances of such use, and extremely difficult to prove the use thereof by persons not licensed by your orators, and the extent of such use, and it would be extremely onerous and burdensome for your orators to bring separate suits against each user to restrain said infringing use; and so, if the defendants, or either of them, shall be allowed to continue to manufacture and supply such instruments for use during the pendency of this suit, your orators will be wholly without adequate remedy in the premises.

26. The defendants, well knowing the premises, but designing and contriving to injure your orators, and to deprive your orators of the benefits, profits and advantages arising and accruing from the exclusive possession, exercise and control of the patented inventions aforesaid to which your orators have been, and are, justly and lawfully entitled, have, without the consent and against the will and protest of your orators, at the city of Philadelphia aforesaid, and elsewhere within the said Eastern District of Pennsylvania, since the first day of February, in the year 1884, jointly made and used, and furnished to others for use, and caused to be made and used, and to be furnished to others for use, and sold and caused to be sold, electric speaking telephones, each of which is constructed and adapted for the transmission of articulate speech by and according to the method described and claimed in said patent to Bell, No. 174,465; and each of which embraces and embodies in one integral organization the inventions and improvements, or material and substantial parts thereof, described and claimed in said patents to Bell, No. 174,465 and No. 186,787 respectively; and still are making

and using, and furnishing to others for use, such electric speaking telephones, and causing the same to be made and used, and to be furnished to others for use, in violation and infringement of your orators' exclusive rights in the premises; but precisely how long the defendants have made, used, furnished to others for use, or sold such infringing telephones; or caused the same to be made, used, furnished to others for use, or sold; or what number of said infringing telephones the defendants have so made, used, furnished to others for use, or sold; or so caused to be made, used, furnished to others for use, or sold; your orators are ignorant for want of a discovery thereof, and pray that the defendants be required to disclose and set forth these matters in their answer hereto.

27. The defendants have been, and are, deriving and receiving considerable gains and profits from and by reason of their making, using, furnishing to others for use, and selling the infringing telephones aforesaid, and thereby have been and are preventing your orators from exercising and enjoying in full measure the exclusive rights and privileges granted by the patents aforesaid; and thus have been, and are, depriving your orators of gains and profits to which your orators have been, and are, justly and equitably entitled. Furthermore, the defendants by taking advantage of the general acquiescence of the public in your orators' exclusive rights aforesaid, and of the consequent absence of ordinary trade competition in respect to electric speaking telephones embracing the said patented inventions, have been able to ask and receive, and have in fact asked and received, for their said infringing telephones, prices greatly in excess of what they could otherwise have obtained; and the defendants have thereby derived and acquired gains and profits which, but for the protection in the market afforded by the existence of your orators' said patents, and by the generally respected rights of your orators thereunder, the defendants would never have been able to realize.

All such gains and profits so derived and acquired by the defendants, and all gains and profits whatsoever which have arisen or accrued to the defendants from or by reason of their said infringements, belong of right to your orators, and would have been ob-

tained and received by your orators, except for the said wrongful acts of the defendants.

28. The defendants have also taken advantage of the extensive demand created by your orators for electric speaking telephones embracing the patented inventions aforesaid, at prices and royalties commensurate with the expenditures of your orators in that behalf, and with the intrinsic value of the said patented inventions; and to the end of appropriating to themselves the trade which thus legitimately belongs to your orators under the protection of the patents aforesaid, the defendants have put upon the market their said infringing telephones, and have offered and furnished the same at prices much less than those established by your orators, the American Bell Telephone Company, as reasonable and adequate compensation for the value of the patented inventions aforesaid, embraced and embodied in the telephones of its own manufacture, and for the time, labor and expense bestowed by your orators in putting the said telephones into extensive use, and in creating the public demand therefor; and the defendants have thereby sought and attempted to disaffect the public in its recognition of your orators' exclusive rights under the said patents, and to disturb and diminish your orators' business of manufacturing and furnishing for use electric speaking telephones embracing the patented inventions aforesaid, and to unsettle and depress the prices and royalties customarily paid to your orators therefor; by reason whereof the defendants have not only diverted to themselves gains and profits which justly and lawfully belong to your orators, but have otherwise greatly damaged and injured your orators.

29. Your orators have requested the defendants to acknowledge their exclusive rights in the premises, and to desist and refrain from their said unlawful acts, and to account for and pay what is justly due to your orators by reason of the said infringements; but the defendants wholly refuse so to do.

On the contrary, they still continue to make, use and furnish to others for use, and to cause to be made, used and furnished to others for use, the said infringing electric speaking telephones, and threaten and intend to continue so to do, in violation and infringement of your orators' exclusive rights granted and secured in and by

said patents to Bell, No. 174,465 and No. 186,787, respectively; and if the defendants are suffered so to continue the said infringements, they will irreparably damage and injure your orators, and depreciate or destroy the value of the exclusive franchise to which your orators are entitled under each of the patents aforesaid, and will deprive your orators of benefits and advantages, for the loss of which there exists no adequate legal remedy.

30. Your orators further show that, in addition to the relief herein sought against the defendants, they are likewise entitled to restrain each and every user of any infringing telephone or telephones which have been, or shall be, made and furnished or disposed of by the defendants in violation of your orators' exclusive rights in the premises, and to recover and collect from each user thereof a suitable sum of money as and for damages and profits in consequence and growing out of such use; and your orators, notwithstanding any proceedings in this cause against the defendants, do not waive any rights or remedies which they may have against each and every person who has, or shall have, used any of the said infringing telephones, but wholly insist upon their said rights and remedies, and aver and assert that they intend to pursue and enforce the same against every such user; but your orators further aver that the defendants are also liable to pay to your orators other sums of money as and for profits by them actually realized, and as and for damages by them directly caused to your orators, by reason of their said infringements and unlawful acts.

31. To the end, therefore, that the defendants may, if they can, show why your orators should not have the relief herein prayed, and may, according to their best and utmost knowledge, remembrance, information and belief, but not under oath, which is hereby expressly waived, full, true, direct and perfect answer make to the matters hereinbefore stated and charged; and that the defendants may be decreed to account for and pay over to your orators all such gains and profits as have, and shall have, resulted and accrued to them from the said unlawful making, using, furnishing to others for use, or selling of electric speaking telephones, embracing or embodying the inventions and improvements, or any material and substantial part thereof, set forth and claimed in said patents to Bell, No. 174,465

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and No. 186,787, respectively; and that in addition to the said profits to be so accounted for, the defendants may also be decreed to pay to your orators the damages which your orators have, and will have, sustained by reason of the said violation and infringement of their exclusive rights aforesaid, and which this honorable Court may assess or cause to be assessed, together with such increase thereof as your Honors may see fit to adjudge; and that the defendants, their attorneys, agents, workmen and servants, may be perpetually enjoined and restrained by the decree of this honorable Court from directly or indirectly making, using, furnishing to others for use, or selling any electric speaking telephones or telephonic apparatus whatsoever, embracing and embodying the inventions and improvements, or any material and substantial part thereof, set forth and claimed in said patents to Bell, No. 174,465 and No. 186,787, or either of them; and that the defendants may likewise be restrained and enjoined to the same effect while this cause is proceeding to final order and decree; and that the defendants may be further decreed to pay the costs of this suit; and that your orators may have such other relief as the equity of this case may require and as your Honors may deem to be just and right.

32. May it please your Honors to grant unto your orators not only a writ of injunction conformable to the prayer of this bill, and an *interim* injunction to the same effect, until further order, but also a writ of *subpœna*, directed to the said defendants, and each of them, and commanding them to appear and answer unto this bill of complaint, and to do and to receive what to your Honors shall seem meet in the premises.

THE AMERICAN BELL TELEPHONE COMPANY,

By W. H. FORBES,
President.

UNITED STATES OF AMERICA,
STATE AND DISTRICT OF MASSACHUSETTS, } ss.

At Boston, in said district on this first day of April, 1884, personally appeared the above-named W. H. Forbes, and made oath; that he is the President of the said American Bell Telephone Company, and duly authorized to act on its behalf in the premises; that

[ENDORSED.]

No. 15. April Sess., 1884.

C. C. U. S., E. D. of Pa.

AMERICAN BELL TELEPHONE COMPANY ET AL.

v.

CLAY COMMERCIAL TELEPHONE COMPANY ET AL.

BILL OF COMPLAINT.

Filed April 24, 1884.

And afterwards, to wit, on the ninth day of August, A. D. 1884, the respondents, by their counsel, William W. Ker, Esq., and Furman Sheppard, Esq., come into court here and file their answers, which being read, are in the words following, to wit:

he has read the foregoing bill of complaint, and understands the contents thereof; and that the same is true of his own knowledge, except such matters as are therein stated on information, which he believes to be true.

Before me,

[SEAL] PHILIP S. STONE,
Notary Public, Suffolk Co.

ANSWER OF THE CLAY COMMERCIAL TELEPHONE COMPANY.

[FILED AUGUST 9, 1884.]

The separate answer of The Clay Commercial Telephone Company, one of the defendants, to the bill of complaint of the American Bell Telephone Company, and the Bell Telephone Company, complainants, against The Clay Commercial Telephone Company, and others, defendants.

This defendant, now and at all times hereafter saving and reserving unto itself all and all manner of benefit, and advantage of exception, which can or may be had or taken to the many errors, uncertainties and other imperfections, in the said complainants' said bill of complaint contained, nevertheless for answer thereunto, or unto so many and such parts thereof as this defendant is advised is, or are, material or necessary for it to make answer unto, this defendant, answering, saith as follows: —

This respondent has been informed, and believes it to be true, that the said Letters Patent of the United States for alleged improvements in telegraphy in the said bill mentioned, dated respectively March 7, 1876, No. 174,465, and January 30, 1877, No. 186,787, were issued to the said Alexander Graham Bell; but this respondent, upon information and belief, denies all and singular the allegations in the said bill, that the said Bell was the original and first inventor of the alleged improvements described and claimed in said respective Letters Patent, and that the same had not been known or used by others in this country, nor patented or described in any printed publication in this or any foreign country

before his alleged invention or discovery, and that the same had not been in public use or on sale for more than two years prior to his said application for the said respective Letters Patent, but alleges the contrary thereof. And the respondent also denies that in the matter of said respective Letters Patent, and in the application therefor, and in the issuing thereof, due proceedings were had in all respects according to the requisitions of the statutes, and of the law, in such case made and provided, but alleges the contrary thereof, and saith, upon information and belief, that said Letters Patent, No. 176,465, were irregularly, unlawfully, and improvidently granted and issued, for the reason, among others, that they were granted and issued in disregard and to the neglect of certain pending caveats and applications then on file in the Patent Office and without notice to the said caveators and applicants; wherefore the respondent saith that said Letters Patent were and are null and void; and it prays that the complainants may be required to make due and legal proof of all and singular their allegations in that behalf in the said bill of complaint contained.

The respondent further saith that in the matter of the said patent of the said Bell, dated March 7, 1876, No. 174,465, it was so proceeded in the Patent Office that, on or about March 26, 1878, in accordance with the act of Congress in such case made and provided, an interference was declared by the Patent Office between the said Bell and divers other rival patentees, and applicants for patents, among whom was one James W. McDonough, who, on the tenth day of April, 1876, had filed in the Patent Office an application for Letters Patent, embracing and claiming the substantial and material part or parts of the alleged invention or discovery claimed by the said Bell in his said patent of March 7, 1876, No. 174,465; that the subject matter involved in the said interference was declared by the said Patent Office to be "a telephonic receiver consisting of the combination in an electric circuit, of a magnet, and a diaphragm supported and arranged in close proximity thereto, whereby sounds thrown upon the line may be reproduced accurately as to pitch and quality"; that in the course of said interference a large body of testimony was taken by the said Bell and by the said McDonough respectively, in which the evidence of their conflicting claims to the

said invention or discovery was fully produced and investigated; that after full consideration, and after the said Bell and the said McDonough had each been fully heard by said examiner, it was finally, on July 21, 1883, decided and adjudged by the said examiner of interferences that the said McDonough, and not the said Bell, was the first and original inventor of "a receiver containing an electro-magnet and a diaphragm supported and arranged in close proximity thereto, and adapted to respond to variations in the electric current passing through the coils of the magnet, when used in connection or combination with a transmitter adapted to create sound-producing fluctuations in the electric current, whether said electrical variations, waves, pulsations, or undulations represented or are derived from sound waves, or mechanical vibrations"; that the apparatus thus described is identical in construction, operation, and effect with that shown, described and claimed in the said Bell patents, where it is used both as a transmitter and a receiver; that it was furthermore decided and adjudged by the said examiner that it was "satisfactorily proved" that said McDonough made and used the said invention above mentioned, as early at least as May, 1875; and that, as to the claim thereto by the said Bell, upon the evidence submitted, it was "impossible to find that he had conceived, much less disclosed, the invention in issue," and that "he does not pretend to have constructed such a receiver, prior to July, 1875." Thereupon, priority of invention was formally and publicly and duly awarded to the said McDonough; and inasmuch as said decision of the said Patent Office is still subsisting in full force and effect, it is in law, as the respondent is advised, to be deemed and taken, by the adjudication of the tribunal in such case made and provided, that the fundamental principle and the substantial devices of the said patents of the said Bell were anticipated by the said McDonough, and that he, the said McDonough, and not the said Bell, is the first and original inventor or discoverer thereof, and is the person who is legally entitled to receive the Letters Patent therefor.

And the respondent, further answering, upon information and belief, saith that the said McDonough, upon due application therefor, received from the said Patent Office three several Letters Patent, numbered and dated as follows, and containing claims which em-

brace substantial and material parts of the things patented by the said Bell, the said patents of the said McDonough being respectively as follows: —

No. 245,534, dated August 9, 1881, in which the claim is as follows: —

"The combination, substantially as hereinbefore set forth, for a telephone-receiving apparatus, of a helix and magnet, and connecting post, to which the wires of the helix are joined, mounted in one end of a frame or holder of wood or such like insulating material; a membrane mounted on the opposite end of said frame or holder, a portion of the face of which membrane presents a material, attached to and supported wholly thereby, capable of being attracted by the magnet, and in close proximity thereto, so that the said membrane shall be caused to vibrate by the action of pulsations in an electric current in the helix around the magnet, with a sound recess at the opposite side of the membranes from the magnet, to confine the sounds received therein and exclude exterior sounds from the ear of the listener, and adapted at the same time to allow the ear of the listener to be placed in close proximity to the membrane, all constructed and arranged to operate substantially in the manner described."

No. 248,002, dated October 4, 1881, in which the claim is as follows: —

"The combination, substantially as hereinbefore set forth, of a transmitting membrane, composed of vellum or any suitable material that is sensitive to the vibrations of sound, and two pieces of conducting material attached to and receiving motion from the same, and included in an electric circuit, a circuit controller resting upon said plates, and suitable means, as shown and described, for adjustably limiting the vibrations of the controller with relation to said plates, the whole combined to operate substantially in the manner and for the purpose set forth."

No. 246,800, dated September 6, 1881, in which the claim is as follows: —

"The combination, substantially as hereinbefore set forth, of a magnet, a helix, and a receiving membrane, a portion of the face of which presents a material attached to and supported wholly by the

membrane, capable of being attracted by the magnet and in close proximity thereto, with connecting wires, a voltaic battery, and a transmitting membrane, conducting pieces, connected thereto and to the circuit wires, a circuit controller resting upon said pieces and entirely supported thereby, and arranged to vibrate in connection with the membrane, and a regulating nut to limit the movement of the controller with relation to said contact-pieces, all combined to operate in the manner set forth, so that the said controller, when at rest, completes the circuit of the battery, and when in motion, by means of sound waves, causes electrical pulsations in the connecting wires and helix around the magnet, and vibrations of the membrane of the receiver."

And the respondent further saith, on information and belief, that in or about November, 1881, the United States Telephone Manufacturing Company, as owner of the above-mentioned patents of the said James W. McDonough, or as working thereunder, filed a bill in equity in the Circuit Court of the United States for the District of Connecticut against the Connecticut Telephone Company, licensed under the said patents of the said Bell, or interested therein and working and operating thereunder, in which said bill said McDonough asserted his rights as prior inventor under his said patents, and alleged and charged that the devices described by the said Bell in his said patents, and made and used under the same by the defendant in said suit, were violations and infringements of the right and title of him, the said McDonough, under the Letters Patent issued to him as aforesaid; that it was asserted and as matter of defence claimed by the defendant in the said suit, that the said American Bell Telephone Company had, by contract and agreement with said McDonough, during the pendency of the said interference above mentioned, acquired all his right, title, and interest under the said Letters Patent, in consideration of a sum of money paid or to be paid or secured to him, the said McDonough; that said suit is proceeding to final hearing, a large amount of testimony having been taken therein; that it involves, as between the said patents of the said Bell and the said patents of the said McDonough, the originality of the substantial and material part or parts of the claims of the said Bell, and is now pending and undetermined in said court. And the

respondent further saith, that the alleged acquisition by the successors of said Bell, of the right of the said McDonough under said interference, was ostensibly claimed by them to be merely for the purpose of quieting their licensees, and protecting them from possible litigation and annoyance in case the said McDonough should be successful in establishing the priority claimed by him in said interference. But the respondent, upon information and belief, saith that the sum offered or agreed to be paid or secured by the successors of the said Bell, under the said alleged agreement of acquisition, was about the sum of $300,000, and that this sum was offered or agreed to be paid, not, as pretended, for the purpose of avoiding litigation, but really from a consciousness, knowledge, and belief that the claims of the patents of the said Bell were invalid for want of originality, and that, in order to save said patents, it was a matter of necessity to buy off the real inventor, even at the cost, fully or approximately, of the very large sum of $300,000.

Further, this respondent saith, upon information and belief, that the said Bell, on or about the ninth day of December, 1876, caused Letters Patent to be taken out in his behalf at London, in the Kingdom of Great Britain, and that, thereafter, in consequence of evidence produced in judicial proceedings, or which otherwise became public, he, or his representatives in that behalf, made and filed certain alterations and disclaimers in the specification or description forming a part of said English Letters Patent, thereby disclaiming many and material matters and things, which, in this country, are claimed by and in behalf of said Bell, whereby the patented claims made by or in behalf of the said Bell, in Great Britain, and those made by him, or in his behalf, in this country, have become, and are, repugnant to, and inconsistent with, each other.

Further, as respects said Letters Patent, dated January 30, 1877, and numbered 186,787, this respondent saith that substantial and material parts of the things therein and thereby described and claimed, were theretofore described and claimed by the said Bell in the said prior Letters Patent of March 7, 1876, No. 174,465; also, that substantial and material parts of the things described and claimed in said Letters Patent of January 30, 1877, No. 186,787, were described

and claimed in prior foreign Letters Patent of the Kingdom of Great Britain, taken out by and for the said Bell, and in his behalf, in the city of London, in England, which said last-mentioned foreign Letters Patent bear date on or about the ninth day of December, A. D., 1876; and that, inasmuch as said subsequent Letters Patent of the United States, numbered 186,787, do not bear even date with the said foreign Letters Patent, and are not limited to expire therewith, the said last-mentioned Letters Patent of the United States were, and are, therefore, null and void.

As to the alleged title of the complainants set forth in the third and fourth paragraphs of said bill, this respondent saith that it has no knowledge or information, save as derived from same bill, concerning the same, or that the said complainants are corporations duly established under the laws of the State of Massachusetts and of the State of Pennsylvania, respectively; and it further says that it is advised, and it accordingly submits, that the said alleged title as set forth in said bill does not authorize the complainants to bring or maintain this bill, or to assert the rights and claim the relief in manner and form as they are therein and thereby asserted and claimed; and also that the said bill is defective for want of proper and sufficient parties thereto. And the respondent prays that it may be entitled to the benefit and advantage of said objections and exceptions in like manner as if it had formally demurred or pleaded to said bill for said causes; and it also prays that the said complainants may be required to make due proof of all and singular the grants, assignments and licenses in said bill mentioned, and of their allegations in this behalf.

Further answering, this respondent saith that it does not admit it to be true, but, on the contrary, denies it to be true, as in said bill alleged, that electric speaking telephones had never been publicly known or used before the grant of said patent, No. 174,465, or that they were first publicly made known by said Bell and were, by him and his licensees, first introduced into public use under the said patents, No. 174,465 and No. 186,787, or that the fact that said Bell was the original and first inventor of said alleged inventions, and that the patents above named are good and valid patents has been generally recognized and acknowledged by those who have

used the said alleged inventions and by the public generally in all parts of the United States, or that the claims of the said Bell and of the American Bell Telephone Company, and their predeces-ors, to the exclusive right to said alleged inventions have been generally acknowledged and acqiesced in, or that several persons have desisted from attempting to make, sell and use telephones, or parts thereof, embracing said alleged inventions, from recognition of the claims of the complainants as valid, or that by reason of any acts of this respondent, the American Bell Telephone Company and its predecessors would have hitherto almost universally enjoyed the sole and exclusive right to practise said alleged inventions. This respondent is not informed, save in and by said bill, how many persons have put said alleged invention in use, or how many telephone exchanges under license from the complainants now exist, or in how many towns they exist, or whether they pay royalty to the said complainants. The respondent, however, admits that telephones of divers forms have been largely and extensively introduced and used throughout the United States, but it denies that such introduction and use are due to, or are a recognition of, and acquiescence in, the claims by said Bell, or by his successors, under said patents, and, on the contrary, alleges that such introduction and u-e have, to a very great extent, arisen from, or been accompanied with, a disregard, rejection and repudiation of such claims, and have been in defiance and in despite thereof.

This respondent furthermore denies it to be true, as in said bill alleged, that the transmission of articulate speech telegraphically, according to the method alleged to have been invented by the said Bell, and patented to him by the two several patents aforesaid, constituted an entirely new industrial art, or that the manufacture and introduction into use of instruments and apparatus for such purpose is an industry which was originally created under the said patents to the said Bell, and which has been developed wholly and solely by the owners of the said patents and their licensees; or that persons attempting to make, sell, use, or furnish for use, electric speaking telephones without license from the complainants, not only violate the exclusive rights claimed to be granted by said patents, but avail themselves of the knowledge and experience which have

been gained by the long-continued labors, trials, efforts, and expenditures of the complainants, their predecessors and licensees, in the development of the telephone and the introduction thereof into use. On the contrary, this respondent, upon information and belief, saith that these allegations and claims are directly contrary to, and in direct conflict with, the publicly well known and the printed and published history of telephony, wherein and whereby it appears that researches and practical and successful results in the said art began and were attained long prior to any supposed discovery or invention therein by the said Bell; that very large numbers of persons in this country and in foreign countries devoted their labor and skill to the creation and development of said art long prior to said Bell, and concurrently with him, and thereby anticipated the alleged inventions of the said Bell mentioned in the said patents, or contributed thereto; that the present established success of telephony, and the merit and excellence of the methods and devices employed therein, are due to the labors of many persons, and to a large number of patents which have been granted in this country as well as in foreign countries; that the said Bell, instead of being entitled thus to claim and appropriate exclusively unto himself the general economic and commercial results and the practical benefit of the combined studies, investigations, and aptitude of other persons in the said art, all of whom have successively and independently contributed to the high degree of development, efficiency and value which it has now attained, is himself but one among many persons of equal merit and originality who have labored in this behalf; that his alleged discoveries or inventions, without the aid and employment of the inventions and discoveries of others, were incapable of accomplishing such results as those mentioned and claimed in said bill, and could never have produced, and in fact never did produce, a practically effective, satisfactorily working, or commercially successful telephone; that speaking telephones arranged and constructed in the manner mentioned and set forth in the said patent of the said Bell, No. 174,465, have never been put in use, and are of no commercial value, and have never been made, except tentatively or experimentally, and have never been on sale, and are, for practical purposes, without utility and inefficient and worthless; that the said complain-

ants, or their predecessors in title, have, from time to time, since the grant of said patents, systematically, and as a part of their commercial policy and business methods, bargained, settled and compromised with, or taken into their service, pay and employment, divers persons who had anticipated the alleged inventions or discoveries of the said Bell, or substantial and material parts thereof, and who made claim thereto, whereby the said Bell and his successors in title were enabled to control, withhold and suppress important testimony which would otherwise have become generally known, and would have restricted, damaged or destroyed the claims or pretensions made under or in behalf of said patents, and were also enabled to acquire for themselves a market, and an extent of business, and, for a considerable period of time, almost a monopoly, which they could not, and would not, otherwise have acquired, and to which they were not rightly and by intrinsic merit entitled.

Respondent, upon information and belief, saith that the complainants do not themselves, in fact, make, sell or use the devices described and claimed in the said patents; that the apparatus or instrument made, used and sold by the complainants is an assemblage or aggregation of various devices, which are the invention or discovery of divers other persons whose respective rights and titles have been from time to time purchased, or otherwise acquired by the complainants, which devices are not described by or included within the said patents; that the material devices described in the said patents were long since abandoned by the said complainants, or their predecessors in title, as impracticable, and the further attempted use of the same was discontinued; and that such abandonment and disuse are well known and notorious, and have been mentioned at least as far back as the year 1878, in various publications devoted to this subject, as, for example, in the Journal of the Society of Telegraph Engineers, published in London, as will appear by reference to the volume of said journal for said last-mentioned year.

As respects the various suits and legal proceedings mentioned in said bill in paragraphs numbered from seven to twenty-two, each inclusive, this respondent, upon information and belief, answering, says that said proceedings, and the facts in the said suits respectively, are not f

said bill; that this respondent was not a party thereto or to any of them, but was and is a stranger thereto, and is not legally or otherwise bound or affected by the results thereof; that the devices used by the respective defendants therein were not similar in their substantial and material parts, or in their mode of operation, to the devices and mode of operation used by this respondent; that many of said suits were not hostilely or earnestly contested or conducted, and were not litigated in good faith; that many of them were terminated by settlements and agreements made by and between the respective parties thereto, with mutual concessions by, and mutual gain and advantage to, both of said parties; that none of them have been reviewed or passed upon by the court of last resort; that the principal aim and design of the litigation in many of said suits were to obtain, or to prevent, some commercial or business purpose, or to accomplish some collateral, adventitious or speculative object, irrespective of the legal questions arising upon the Letters Patent therein sued upon, and irrespective of the legal determination of the questions of originality and of infringement arising in said suits; that much of the evidence mentioned and set forth in the statements, averments, and references to patents, publications, and persons, which is contained in this respondent's answer, was not before the courts in the said suits; that since the commencement of said suits the general subject matter of said litigation, and many of the material specific questions involved, have received much fuller and more accurate investigation, elucidation and illustration by divers scientific and skilled persons in this country and in foreign countries, whereby new principles and facts have been ascertained, new views have been elicited and earlier views disproved, experience in telephony has been enlarged, research into its earlier history has been extended, and the knowledge appertaining to the general subject has been greatly increased, expanded and enriched; that the views expressed by the courts in said suits are not, in many substantial and material respects, accordant and consistent with each other, or justified by the actual testimony and facts before the said courts, or in harmony or agreement with other judicial opinions, or with the present prevailing or preponderating scientific belief; and that the opinions formed and expressed in said suits, and the decrees ren-

dered therein, were largely based upon, or influenced by, unproven and unwarranted assumptions both of fact and of scientific principles, and upon agreements of counsel, or concessions made by counsel, and upon feeble, imperfect, insufficient and inadequate defences, and in a large number of said cases upon an entire absence of defence.

And inasmuch as the said complainants have in their said bill mentioned and introduced said legal proceedings, and have sought to derive a benefit and an advantage therefrom, and to establish a right by virtue thereof, this respondent is advised that it thereby becomes entitled, and it accordingly prays leave, to avail itself of the same, and to refer to and produce the pleadings, docket entries, testimony, judgments, and decrees therein respectively, with like effect as if the same were now here fully and at large set forth.

This respondent denies it to be true, as in said bill alleged, that it has at the city of Philadelphia, or elsewhere, since the first day of February, in the year 1884, or at any other time, made and used, or furnished to others to be used, or sold, or caused to be sold, electric speaking telephones, constructed and adapted for the transmission of articulate speech, by and according to the method described and claimed in said patent to the said Bell, No. 174,465, and embracing and embodying in one integral organization the alleged inventions and improvements, or material and substantial parts thereof, described and claimed in said patents to said Bell, No. 174,465 and No. 186,787 respectively. On the contrary, this respondent saith, that the telephones made, used and sold by it have been made and constructed under and in pursuance of certain Letters Patent of the United States, issued and granted, upon due application, and in conformity with law, unto one Henry Clay, as the first and original inventor of said patented improvements respectively, and by him duly assigned to this respondent, which said Letters Patent are respectively of the dates, numbers, and titles, following; to wit, May 8, 1883, No. 277,112, for a new and useful improvement in Telephones; July 3, 1883, No 280,351, for Switch-board for Telephones; July 3, 1883, No. 280,451, for Telephone Call-bell; July 3, 1883, No. 280,580, for Transmitter for Telephones; Nov. 6, 1883, No. 288,017, for Telephonic Transmitter. And the respond-

ent saith, that the devices and methods of operation set forth in these said several Letters Patent, and used by the respondent, are not similar to, but are wholly different from, the devices described and claimed in the said Letters Patent of the said Bell, and are not violations or infringements of said Letters Patent, and do not embody or embrace the method, principle, operation, or construction therein or thereby set forth, described and claimed.

This respondent further saith, that the two several Letters Patent in the said bill mentioned embrace, numerically, thirteen claims; that said bill does not indicate which of said several claims are infringed by this respondent; that the patent of Jan. 30, 1877, No. 186,787, is for certain specific devices, modes of operation, or combinations, none of which are used or employed by this respondent; and that as respects the patent of March 7, 1876, No. 174,465, the system, combination, methods and devices claimed therein, are not used or employed by this respondent; and the more comprehensive claims therein are based upon distinctions, suppositions and theories, none of which, even if the same be true, original, and patentable, which this respondent denies, have any relevancy, pertinency or applicability to the devices or methods employed by this respondent.

And furthermore, as respects said patent, No. 174,465, and the respective claims thereof, the respondent saith that the telephonic devices used by it do not constitute a system of telegraphy in which a receiver is set in vibration by the employment of undulatory currents of electricity as set forth in said patent; nor do the respondent's devices contain a combination of a permanent magnet and a conducting wire, in which the conducting wire can be set in vibration in the neighborhood of the permanent magnet, or the permanent magnet can be set in vibration in the neighborhood of the conducting wire, or in which the permanent magnet and the conducting wire both simultaneously can be set in vibration in each other's neighborhood; nor do the respondent's devices produce undulations in a continuous voltaic current by means of the motion or vibration of bodies capable of inductive action, or of the conducting wire in the neighborhood of such bodies; nor do they produce undulations in a continuous voltaic current by gradually increasing and diminishing the resistance of the circuit, or the power of the battery as set forth in

said patent; nor do said devices embody the method or apparatus described in said patent for transmitting vocal or other sounds telegraphically in manner and form as set forth in said patent.

And as respects said Letters Patent No. 186,787, the respondent saith that it does not use an electric circuit, connecting two or more instruments, or electric transmitting and receiving instruments, united upon an electric circuit, as set forth in said patent; nor does the respondent use the combination with an electro-magnet of a plate of iron or steel, or other material, which is thrown into vibration by the movement of surrounding air, or by the attraction of a magnet as a transmitting instrument; nor does it use the means described in said patent of adjusting the relative position of a plate and electro-magnet, nor the mechanical equivalents thereof; nor does it use in combination with a telephone, such as described in said patent, a coil upon the ends of a magnet, a sounding box or a speaking or hearing tube, or the combination of a permanent magnet with a plate, with coils upon the end or ends of said magnet nearest the plate, in manner and form as set forth and claimed in said patent.

And further answering, this respondent, upon information and belief, saith that the said respective Letters Patent, in the said bill mentioned, were and are null and void, and that the said complainants are not entitled to the relief prayed thereby, or any relief against this respondent, for the further reason, among others, that the said alleged invention or discovery in said respective Letters Patent mentioned, described or claimed, or the substantial and material part or parts thereof, claimed as new and original, was or were, prior to the alleged invention or discovery thereof by the said Bell, known to and used by divers persons, and among others, by the following named persons, respectively, who used the same at the following named places, respectively, to wit: —

James W. McDonough, now or late of Chicago, in the State of Illinois, who used the same at said Chicago and at New York City, and elsewhere.

Daniel Drawbaugh, now or late of Eberly's Mills, county of Cumberland, in the State of Pennsylvania, who used the same at said Eberly's Mills aforesaid, and elsewhere.

Elisha Gray, now or late of Highland Park, in the State of Illinois, who used the same at Cleveland, in the State of Ohio, and at said Highland Park, and elsewhere.

Thomas A. Edison, now or late of Menlo Park, in the State of New Jersey, who used the same at said Menlo Park and at New York City, and elsewhere.

Amos E. Dolbear, now or late of Somerville, in the State of Massachusetts, who used the same at said Somerville, and elsewhere.

Philip H. Vanderweyde, now or late of Brooklyn, in the State of New York, who used the same at New York City, and elsewhere.

W. F. Channing, now or late of Providence, in the State of Rhode Island, who used the same at said Providence, and elsewhere.

Benjamin F. Edwards (now deceased), formerly or late of Boston, in the State of Massachusetts, who used the same at said Boston, at Washington in the District of Columbia, at New York City, and elsewhere.

James Hamblett, Jr., now or late of Brooklyn, in the State of New York, who used the same at Boston, in the State of Massachusetts, at Washington in the District of Columbia, at New York City, and elsewhere.

Edward Farrand, now or late of Keene, in the State of New Hampshire, who used the same at said Keene, and elsewhere.

Antonio Meucci, now or late of Clifton, in Staten Island, in the State of New York, who used the same at said Clifton, at New York City, and elsewhere.

W. S. Voelker, now or late of Morton, in the State of Pennsylvania, who used the same at Philadelphia in said State, at said Morton, and elsewhere.

Edward E. Pickering, now or late of Cambridge, in the State of Massachusetts, who used the same at Boston, and also at said Cambridge, in said State.

A. G. Holcombe, now or late of Newport, in the State of Rhode Island, who used the same at said Newport, and elsewhere.

In addition to the foregoing persons this respondent, upon information and belief, saith that divers other persons had similar prior knowledge, and made similar prior use of said alleged invention or discovery, whose names and residences, and the places of which use,

said patent; nor do said devices embody the method or apparatus described in said patent for transmitting vocal or other sounds telegraphically in manner and form as set forth in said patent.

And as respects said Letters Patent No. 186,787, the respondent saith that it does not use an electric circuit, connecting two or more instruments, or electric transmitting and receiving instruments, united upon an electric circuit, as set forth in said patent; nor does the respondent use the combination with an electro-magnet of a plate of iron or steel, or other material, which is thrown into vibration by the movement of surrounding air, or by the attraction of a magnet as a transmitting instrument; nor does it use the means described in said patent of adjusting the relative position of a plate and electro-magnet, nor the mechanical equivalents thereof; nor does it use in combination with a telephone, such as described in said patent, a coil upon the ends of a magnet, a sounding box or a speaking or hearing tube, or the combination of a permanent magnet with a plate, with coils upon the end or ends of said magnet nearest the plate, in manner and form as set forth and claimed in said patent.

And further answering, this respondent, upon information and belief, saith that the said respective Letters Patent, in the said bill mentioned, were and are null and void, and that the said complainants are not entitled to the relief prayed thereby, or any relief against this respondent, for the further reason, among others, that the said alleged invention or discovery in said respective Letters Patent mentioned, described or claimed, or the substantial and material part or parts thereof, claimed as new and original, was or were, prior to the alleged invention or discovery thereof by the said Bell, known to and used by divers persons, and among others, by the following named persons, respectively, who used the same at the following named places, respectively, to wit: —

James W. McDonough, now or late of Chicago, in the State of Illinois, who used the same at said Chicago and at New York City, and elsewhere.

Daniel Drawbaugh, now or late of Eberly's Mills, county of Cumberland, in the State of Pennsylvania, who used the same at said Eberly's Mills aforesaid, and elsewhere.

Elisha Gray, now or late of Highland Park, in the State of Illinois, who used the same at Cleveland, in the State of Ohio, and at said Highland Park, and elsewhere.

Thomas A. Edison, now or late of Menlo Park, in the State of New Jersey, who used the same at said Menlo Park and at New York City, and elsewhere.

Amos E. Dolbear, now or late of Somerville, in the State of Massachusetts, who used the same at said Somerville, and elsewhere.

Philip H. Vanderweyde, now or late of Brooklyn, in the State of New York, who used the same at New York City, and elsewhere.

W. F. Channing, now or late of Providence, in the State of Rhode Island, who used the same at said Providence, and elsewhere.

Benjamin F. Edwards (now deceased), formerly or late of Boston, in the State of Massachusetts, who used the same at said Boston, at Washington in the District of Columbia, at New York City, and elsewhere.

James Hamblett, Jr., now or late of Brooklyn, in the State of New York, who used the same at Boston, in the State of Massachusetts, at Washington in the District of Columbia, at New York City, and elsewhere.

Edward Farrand, now or late of Keene, in the State of New Hampshire, who used the same at said Keene, and elsewhere.

Antonio Meucci, now or late of Clifton, in Staten Island, in the State of New York, who used the same at said Clifton, at New York City, and elsewhere.

W. S. Voelker, now or late of Morton, in the State of Pennsylvania, who used the same at Philadelphia in said State, at said Morton, and elsewhere.

Edward E. Pickering, now or late of Cambridge, in the State of Massachusetts, who used the same at Boston, and also at said Cambridge, in said State.

A. G. Holcombe, now or late of Newport, in the State of Rhode Island, who used the same at said Newport, and elsewhere.

In addition to the foregoing persons this respondent, upon information and belief, saith that divers other persons had similar prior knowledge, and made similar prior use of said alleged invention or discovery, whose names and residences, and the places of which use,

when the same shall have been more fully ascertained, the respondent respectfully craves leave hereafter to set forth by way of supplement, amendment or addition to this answer, with like effect as if the same were now here mentioned and contained.

This respondent, upon information and belief, also saith that the said respective Letters Patent in the said bill mentioned were and are null and void, and that the said complainants are not entitled to the relief prayed, or any relief, against this respondent, for the further reason, among others, that the said alleged invention or discovery, in said respective Letters Patent mentioned, described or claimed, or the substantial and material part or parts thereof, claimed as new and original, had been, prior to the alleged invention or discovery thereof by the said Bell, mentioned, described or claimed in divers Letters Patent, granted and issued to divers persons, and among others to the following-named persons respectively, and dated and numbered respectively as follows, to wit: —

Letters Patent of the United States, No 166,095, dated July 27, 1875, granted to Elisha Gray.

Letters Patent of the United States, No. 141,777, dated August 12, 1873, granted to Thomas A. Edison and George Harrington.

Letters Patent of the United States, No. 156,897, dated November 17, 1874, granted to William Thomson.

Letters Patent of Great Britain, No. 8,345, dated January 21, 1840, granted to Charles Wheatstone.

Letters Patent of Great Britain, No. 2.646, dated July 29, 1879, granted to J. H. Johnson.

Letters Patent of Great Britain, No. 974, dated March 16, 1875, and granted to John Henry Johnson.

Letters Patent of the United States, No. 165,728, dated July 20, 1875, and granted to Elisha Gray.

Letters Patent of the United States, No. 166,094, dated July 27, 1875, and granted to Elisha Gray.

Letters Patent of the United States, No. 173,460, dated February 15, 1876, and granted to Elisha Gray.

Letters Patent of the United States, No. 173,618, dated February 15, 1876, and granted to Elisha Gray.

Letters Patent of Great Britain, No. 1,874, dated May 1, 1876, and granted to George Tomlinson Bousfield.

Letters Patent of the United States, No. 186,340, dated January 16, 1877, and granted to Elisha Gray.

Letters Patent of the Dominion of Canada, No. 4,749, dated July 7, 1875, and granted to Elisha Gray.

Letters Patent of the United States, No. 175,971, dated April 11, 1876, and granted to Elisha Gray.

Letters Patent of Great Britain, No. 938, dated April 27, 1858, and granted to David Hughes.

Letters Patent of Great Britain, No. 1,044, dated October 8, 1870, to Cromwell Fleetwood Varley.

Letters Patent of the United States, No. 78,495, dated June 2, 1868, to Cromwell Fleetwood Varley, for improvement in telegraphing.

Letters Patent of Great Britain, to Edwin Chabot, executor of George Tomlinson Bousfield, for an Invention relating to Electro-harmonic Telegraphs, bearing date May 4, 1876, No. 1,874.

Letters Patent of Great Britain, to Peter Jensen, dated September 2, 1874, No. 2,999, for an Invention of Improvements in Transmitting and Printing Telegraphic Messages and in apparatus therefor.

Letters Patent of Great Britain, to Peter Jensen, for an Invention of Improvements in Telegraphy, dated February 29, 1876, No. 843.

Letters Patent of the United States, to Thomas Alva Edison, for Telegraphic Apparatus, bearing date January 19, 1875, No. 158,787.

Letters Patent of Great Britain to William Petrie, for Electro-magnetic Engine, dated April 27, 1841, No. 8,937.

Letters Patent of Great Britain, to Sören Hjorth, for Electro-magnetic Engine, dated October 11, 1854, No. 2,199.

Letters Patent of Great Britain, to Alfred Apps, for Electrical Apparatus, dated January 24, 1867, No. 177.

Letters Patent of Great Britain, to Sir William Thomson, for Electrical Telegraph Transmitting Instruments, dated November 23, 1870, No. 3,069.

Letters Patent of Great Britain, No. 11,894, dated October 7, 1847, and granted to Pierre Antonie Joseph Dujardin, for Improvements in electro-magnetic appliances.

Letters Patent of Great Britain, No. 2,103, dated September 17, 1855, and granted to Charles Tilston Bright and Edward Brailsford Bright, for Improvements in Electric Telegraphs, and in apparatus connected therewith.

In addition to the foregoing Letters Patent, the respondent, upon information and belief, saith that divers other Letters Patent of this country, and of foreign countries, have been granted to divers persons for the said alleged invention, or discovery, the particulars of which, when the same shall have been more fully ascertained, the respondent respectfully craves leave hereafter to set forth by way of supplement, amendment or addition to this answer, with like effect as if the same were now here mentioned and contained.

Further answering, this respondent, upon information and belief, saith that the said respective Letters Patent in the said bill mentioned were and are null and void, and that the said complainants are not entitled to the relief prayed, or any relief, against this respondent, for the further reason, among others, that the said alleged invention or discovery in said respective Letters Patent mentioned, described or claimed, or the substantial and material part or parts thereof, claimed as new and original, had been prior to the supposed invention or discovery thereof by the said Bell, made known, mentioned and described in divers printed publications, and, among others, in the following, and in the publications cited, mentioned or referred to therein respectively, to wit: —

Electricity and Magnetism; by Fleeming Jenkins, published in London, England, and New York, N. Y., in the year 1873, at pages 333 and 334, and others.

The Electric Telegraph; by R. Sabine, published in London, England, in the year 1867, at pages 45, 46, 136, 137, 138, and others.

The Electric Telegraph; by Dr. Lardner, new edition revised by E. B. Bright, published in London, England, in the year 1867, at pages 164, 165, 166 and 167, and others.

The Telegraph Journal; published in London, England, in the year 1872, Vol. I., at page 4, and others.

Electricity; by R. H. Ferguson, published in London, England, and at Edinburgh, Scotland, in the year 1867, at pages 257, 259, and others.

The Telegrapher; published in New York, N. Y., in the year 1869, Vol. V., No. 39.

The Manufacturer and Builder; published in New York in the year 1869, Vol. I., at page 129, and others.

Wonders of Electricity; by J. Baile, published in New York in the year 1872, at pages 140, 141, 142, 143, and others.

The Telegraph Journal; published in London in the year 1875, Vol. III., at pages 286, 287, 288, and others; also same Journal for May 15, 1876, pages 148–9, and others; also same Journal for October 1, 1876.

Transactions of Royal Scottish Society of Arts; published in Edinburgh, Scotland, Vol. VI., 1864, Appendix Q, at pages 184, 187, and others.

Annual Report of the American Association for the Advancement of Science, for 1869, on the Audible Transmission of Musical Melodies by Means of the Electric Telegraph, by P. H. Vanderweyde, page 278.

Knight's American Mechanical Dictionary, 1876, Article Telephone, pages 2, 514, and others.

London Telegraph and Electric Review; Vol. I., November, 1872, 1873.

Journal of the Franklin Institute; published in Philadelphia, for 1861, at page 420, and others.

A Treatise on Electricity; by J. T. Sprague; published in London, England, 1875, page 104, and following pages.

The English Mechanic and World of Science; published in London, No. 594, August 11, 1876; also an article in the same journal of the 26th of November, 1875.

Physical Technics; by Dr. J. Frick, translated by John D. Easter; published in Philadelphia, 1862, page 178–9, and others.

Cyclopædia of Science Simplified; by J. H. Pepper, Philadelphia, 1871, pages 5 and 6, also pages 520, 521, 522, 523, 524, 525, and others.

Experimental Researches in Electricity; by Michael Faraday; Vol. III., London, 1855, pages 333, 334, 335, 336, and following pages.

Year Book of Facts in Science and the Arts; by Charles W. Vincent; London and Berlin, 1875, page 138, and others.

The Scientific American; published in New York; of March 4, 1866, also same paper of May 25, 1872, page 352, and others containing article on Acoustic Telegraph, by Prof. Weinhold of Chemnitz, Germany.

Journal of the Franklin Institute; published in Philadelphia, Third Series, Vol. LXII., for July, 1871, pages 8 and 9, and others.

Sound; by John Tyndall, LL. D.; published in London, England, 1867, pages 40, 41, 195, and following pages, and page 257, and following pages.

Journal of the Society of Telegraph Engineers; published in London, England, 1878, Vol. VII., page 267, and following pages; also same journal for 1880, Vol. IX., pages 23, 24, 69, 70 and others.

Proceedings of the Dublin Royal Society; for 1877, page 46, and others.

Barrett upon the Telephone, *Old and New:* published in London, England, 1878, page 73, and others.

The Telephone; a lecture entitled Researches in Electric Telephony, by Professor Alexander Graham Bell, delivered before the Society of Telegraph Engineers, October 31, 1877. Published by the society. London, E. and F. N. Spon, 46 Charing Cross; New York, 446 Broom Street, 1878; pages 6 and 7, and also the several and respective books and publications named, mentioned or referred to in and by the several and respective foot-notes contained in the said pages, said pages and the references contained in the foot-notes thereto being as follows: —

"And here I may remark, that, although the conception of the undulatory current of electricity is entirely original with myself, methods of producing sound by means of intermittent and pulsatory currents have long been known. For instance, it was long since discovered that an electro-magnet gives forth a decided sound when it is suddenly magnetized or demagnetized. When the circuit upon which it is placed is rapidly made and broken, a succession of explosive noises proceeds from the magnet. These sounds produce upon the ear the effect of a musical note when the current is interrupted a sufficient number of times per second. This discovery of 'Galvanic Music,' by Page,* in 1837, led inquirers in different parts

of the world almost simultaneously to enter into the field of telephonic research; and the acoustical effects produced by magnetization were carefully studied by Marrian,† Beatson,‡ Gassiot,§, De la Rive,‖ Mateucci, ¶ Guillemin,* Wertheimer,† Wartmann,‡ Janniar,§ Joule,‖ Laborde,¶ Legat,** Reis,†† Poggendorff,‡‡ Du Moncel,§§ Delezenne,‖‖ and others.¶¶ It should also be mentioned that Gore*** obtained loud musical notes from mercury, accompanied by singularly beautiful crispations of the surface during the ccurse of experiments in electrolysis; Page††† produced musical tones from Trevelyan's bars by the action of the galvanic current; and further, it was discovered by Sullivan‡‡‡ that a current of electricity is generated by the vibration of a wire composed partly of one metal and partly of another. The current was produced so long as the wire emitted a musical note, but stopped immediately upon the cessation of the sound.

* C. G. Page, "The Production of Galvanic Music," Silliman's Journ., 1837, xxxii., p. 396; Silliman's Journ., July, 1837, p. 354; Silliman's Journ., 1838, xxxiii., p. 118; Bibl. Univ. (new series), 1839, ii. p. 398.

† J. P. Marrian, Phil. Mag., xxv., p. 382; Inst., 1845, p. 20; Arch de l'Electr., v. p. 195.

‡ W. Beatson, Arch de l'Electr., v. p. 197; Arch. de Sc. Phys. et Nat. (2d series), ii., p. 113.

§ Gassiot. See "Treatise on Electricity," by De la Rive, i., p. 300.

‖ De la Rive, Treatise on Electricity, i., p. 300; Phil. Mag., xxxv., p. 422; Arch de l'Electr., v. p. 200; Inst., 1846, p. 83; Comptes Rendus, xx., p. 1287; Comp. Rend., xxii., p. 432; Pogg. Ann., lxxvi., p. 637; Ann. de Chim. et de Phys., xxvi., p. 158.

¶ Matteucci, Inst., 1845 p. 315; Arch. de l'Electr, v., 389.

* Guillemin, Comp. Rend., xxii, p. 264; Inst., 1846, p. 30; Arch. de Sc. Phys. (2d series), i., p. 191.

† G. Wertheim, Comp. Rend., xxii., pp. 336, 544; Inst., 1846, pp. 65, 100; Pogg. Ann., lxviii., p. 140; Comp. Rend., xxvi., p. 505; Inst., 1848, p. 142; Ann. de Chim. et de Phys., xxiii., p. 302; Arch. de Sc. Phys. et Nat., viii., p. 206; Pogg. Ann., lxxvii., p. 43; Berl. Ber., iv., p. 121.

‡ Elie Wartmann, Comp. Rend., xxii., p. 544; Phil. Mag. (3d series), xxviii., p. 544; Arch de Sc. Phys. et Nat. (2d series), i., p. 419; Inst., 1846, p. 290; Monatschr, de Berl. Akad., 1846, p 111.

§ Janniar, Comp. Rend., xxiii., p. 319; Inst., 1846, p. 269; Arch. de Sc. Phys. et Nat. (2d series), ii., p. 394.

‖ J. P. Joule, Phil. Mag., xxv., pp. 76, 225; Berl. Ber., iii. p. 489.

¶ Laborde, Comp. Rend., l. p. 692; Cosmos, xvii., p. 514.

** Legat, Brix., Z. S., ix., p. 125.

†† Reis, "Telepbonie," Polytechnic Journ., clxviii., p. 185; Böttger's Notizbl., 1863, No. 6.

‡‡ J. C. Poggendorff, Pogg Ann., xcviii., p. 192; Berliner Monatsber, 1856, p. 133; Cosmos, ix., p. 49; Berl. Ber., xii., p. 241; Pogg. Ann., lxxxvii., p. 139.

§§ Du Moncel, Exposé, ii , p. 125; also, iii., p. 83.

||| Delezenne, "Sound produced by Magnetization," Bibl. Univ. (new series), 1841 xvi., p. 406.

¶¶ See London Journ., xxxii., p. 402, Polytechnic Journ., ex., p. 16; Cosmos, iv., p. 43; Glösener — Traité général, &c., p. 350; Dove. Repert, vi., p. 58; Pogg. Ann., xliii., p. 411; Berl. Ber., i., p. 144; Arch. de Sc. Phys. et Nat., xvi , p. 406; Kuhn's Encyclopædia der Physik, pp. 1014–1021.

*** Gore, Proceedings of Royal Society, xii., p. 217.

††† C. G. Page, "Vibration of Trevelyan's Bars by the Galvanic Current," Silliman's Journal, 1850, ix., pp. 105–108.

‡‡‡ Sullivan, "Currents of Electricity produced by the Vibration of Metals." Phil. Mag. 1845, p. 261; Arch. de l'Electr., x., p. 480.

Reference is also made by the respondent to the remaining portions of said publication and to the several and respective persons, books, publications and proceedings referred to and mentioned therein and in the foot-notes thereof.

Der Elecktromagnetische Telegraph; by H. Schellen, published at Brunswick, Germany, in 1867, pages 411, 412, 413, 414, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 468, and 469, and others.

Zeitschrift des Deutsch-Oesterreichischen Telegraphen-Vereins; published in Berlin, Prussia, in the year 1862. Vol. IX., at page 125, and others.

Die Fortschritte der Physik; von Dr. E. Jochmann, 1861, at pages 172, 173; and 1863, page 96, and others.

Polytechnisches Journal; von Dr. E. M. Dingler, Augsburg, 1863. Nos. 168, 169, pages 29, 33, 185, 399, and others.

Deutsche Klinik; No. 48, Berlin, November 28, 1863, pages 468, 469, and others.

Deutsche Industrie Zeitung; for 1863, Chemnitz, No. 16, page 184 and others; No. 18, page 208, and others; and No. 22, page 249, and others.

Frankfurter Conversationsblatt; November 29, 1861, and June 30, 1863.

Polytechnisches (Physikalisches) Centralblatt; 1863, pages 857, 859, and others.

Polytechnisches Notizblatt; von Prof. Dr. Reed, Böttger, Frankfurt, A. M. No. 618, Jahrgang 1863, pages 81, 84, and others; and also same year, No. 15, page 225, and others.

Didaskalia, Blaetter fur Geist, Gemueth and Publicitaet; for May 8 and May 12, 1862, and also for September 28, 1864, No. 232.

Die Gartenlaube; published at Leipsic, 1862. No. 51, page 807 and following pages; also No. 51, December, 1863.

Die Neueren. Apparate der Akoustik; von Fr. Pisko, Wien, 1865, pages 94 and following pages; also, same book, pages 241 and following pages.

Jahresbericht des Physikalischen Vereins; Frankfurt, A. M., for the year 1860, 1861; pages 57, 64, and others; and same work for 1863, page 129 and following pages.

Zeitschrift des Deutsch-Oesterreichischen Telegraphen-Vereins; published at Berlin, Prussia, 1862. Vol. IX., page 125 and others.

Müller Pouillett's Lehrbuch der Physik and Meteorologie; published at Brunswick, Hanover, sixth edition, 1863. Vol. II., page 352 and following pages, and seventh edition of said book, 1868, Vol. II., page 386 and following pages.

Carl Kuhn's Handbuch der Angewandten Elecktricitätslehre; published at Leipsic, 1866, page 1017 and following pages, being Vol. XX. of Karsten's Allgemeine Encyclopädie der Physik.

Aus der Natur, published at Leipsic in 1862, Vol. XXI., pages 470, 474, and others.

Exposé des Applications de l'Electricité; by Count du Moncel, 2d Edition, Paris, 1856, Vol. I., page 246 and following pages.

In addition to the foregoing printed publications, this respondent, upon information and belief, saith that divers other printed publications had made known, mentioned, and described the said alleged invention or discovery, which said other prior printed publications, when the same shall have been more fully ascertained, the respondent respectfully craves leave hereafter to set forth by way of supplement, amendment, or addition to this answer, with like effect as if the same were now here mentioned and contained.

This respondent, further answering, saith that it is informed and advised, and it believes and respectfully submits, that the respective Letters Patent of the said Bell, in the said bill mentioned, are null and void, for the reasons, among others, that the specifications or descriptions attached to said respective Letters Patent are not, as respects the material and important parts thereof, in such full

clear, concise, and exact terms as, at the time when said respective Letters Patent were granted, to have enabled, or as now to enable, any person skilled in the art or science to which said alleged inventions appertain, or with which they are most nearly connected, to make, construct, and use the same; that the principle or nature of said alleged invention is not fully, adequately, or intelligibly explained so as to distinguish it from other inventions; that the part, improvement and combination claimed by the said Bell is not particularly pointed out or distinctly claimed; that the said specifications do not clearly and intelligibly distinguish between the prior state of the art, and things theretofore known and in use, and the things claimed in said specifications; that many of the combinations claimed in said patents are unpatentable as combinations; that many of said claims are vague, ambiguous, uncertain, and indefinite, and that others of said claims are unlawful attempts to appropriate broadly, unrestrictedly, and exclusively the application and employment of principles of science, and the operation of laws or of properties of magnetic or electric action, which said attempted appropriation, as the respondent is advised, is unpatentable; that said respective specifications do not describe a manner of constructing or operating a practical or successful telephone, and that the instrumentalities do not represent, and could not at the time when said Letters Patent were granted, and cannot now, be made to constitute, a telephone capable of working usefully, effectually, or serviceably, without the necessity of resorting to experiments and of obtaining further information, and without the employment of other and additional inventive and constructive skill; that the said Bell surreptitiously or unjustly obtained the said patents for that which was in fact invented or discovered by one Elisha Gray, now or late of Highland Park, in the State of Illinois; by one Daniel Drawbaugh, now or late of Eberly's Mills, in the State of Pennsylvania; by one James W. McDonough, now or late of Chicago, in the State of Illinois; by one Antonio Meucci, now or late of Clifton, in Staten Island, in the State of New York; by one Amos E. Dolbear, now or late of Somerville, in the State of Massachusetts, and by other persons, whose names, when the same shall have been more fully ascertained,

the respondent craves leave hereafter to add hereto, all of whom were using reasonable diligence in adapting and perfecting the same; that the said alleged inventions or discoveries had been in public use and on sale in this country for more than two years prior to the application of the said Bell for the said patents respectively; and also, that the same, or the material and substantial part or parts thereof claimed as new and original, had been abandoned to the public prior to said application.

And this respondent, upon information and belief, further answering, saith that the distinction or difference asserted in said patents between undulatory currents and interrupted or pulsatory currents, is imaginary and unreal, and has no actual existence, and constitutes no patentable foundation of novelty; that it furnishes no legal or actual ground of distinction between the alleged principle of the alleged invention or discovery of the said Bell, as claimed in the said patents, and the methods and principles of action and operation well known and used in similar or analogous devices prior thereto; that it cannot constitute any intelligible, adequate, or patentable basis of invention and discovery, or any practical or determining test or criterion either of originality or of infringement; that it is insufficient and inadequate, either in fact or in law, to extend the construction of the patents of the said Bell, further than or beyond a claim to the several devices or the special method of operation, mentioned, set forth, and described by him therein; that such construction can not be thus extended; that even, as respects said alleged or assumed undulatory currents, if it be otherwise than as above mentioned, said alleged currents and the employment, application and utilization thereof are, and can legally be, claimed in and by said patents, only in connection or combination with the several and respective devices, instrumentalities and methods therein mentioned, set forth, and described, which said devices, instrumentalities and methods are not contained, used or employed in and by the devices, instrumentalities or methods used or employed by this defendant; that the actual kind of current, whether it be termed undulatory, or whether it be termed interrupted, which is, in fact, necessary for the transmission of conversation, had been long known and used for that purpose, or

for analogous purposes, and can not, therefore, be legally appropriated by the said patents of the said Bell, or by any proper or valid construction thereof; that the vibratory or undulatory currents of electricity, mentioned and described in said respective Letters Patent, are not different in nature, kind, function or method of operation and action, from currents of electricity which had theretofore been known, and which had been publicly employed for the same, or for a substantially similar or an analogous purpose; and that the alleged new use thereof by the said Bell is a non-patentable equivalent, or a double use and application thereof, which does not constitute a legal subject-matter of appropriation or claim.

Wherefore, and by reason of the premises, and of all and singular the matters and things aforesaid, both of law and of fact, the respondent is advised and informed, and accordingly respectfully submits, that the complainants are not entitled to the remedy and relief by way of injunction, profits, damages or costs, as prayed by them in their said bill against the respondent, or to any remedy or relief whatsoever against the respondent, but that on the contrary it is herein and hereby manifestly shown and made to appear that the said bill of complaint is unfounded and unjust and contrary to law, equity and good conscience, and that the same should therefore be dismissed.

And this respondent prays that so many and such parts of the contents of the foregoing answer as are, or might more properly be, matters of demurrer, may avail the respondent as and by way of demurrer, and may be deemed and taken to be such; and that so many and such parts of the contents thereof as are, or might more properly be, matters of plea, may avail the respondent as and by way of plea or pleas, and may be deemed and taken to be such.

Without this, that there is any other matter, cause or thing in the said complainants' said bill of complaint contained, material or necessary for this defendant to make answer unto, and not herein and hereby well and sufficiently answered, confessed, traversed and avoided, or denied is true, to the knowledge or belief of this defendant; all which matters and things this defendant is ready and willing to aver, maintain, and prove, as this Honorable Court shall direct,

and humbly prays to be hence dismissed with its reasonable costs and charges, in this behalf most wrongfully sustained.

THE CLAY COMMERCIAL TELEPHONE COMPANY,

By JOHN C. SCOTT,
President.

WM. W. KER,
FURMAN SHEPPARD,
Counsel for said Defendant.

CITY AND COUNTY OF PHILADELPHIA, } ss.
STATE OF PENNSYLVANIA, }

John C. Scott, being duly sworn, deposeth and saith that he is the president of the said the Clay Commercial Telephone Company, the abovenamed defendant; that he has read the foregoing answer of the said company, and has signed the same as president of said company; that the matters therein stated as the acts of said company are, to the best of his knowledge, true; and that the other matters and things therein stated are true to the best of his knowledge, information and belief.

JOHN C. SCOTT.

Sworn and subscribed before me this eighth day of August, A. D. 1884.

ROBERT HUTCHINSON, *Notary Public.*

THE JOINT AND SEVERAL ANSWER

Of John C. Scott, James McMillen, George W. Bratton, Samuel P. Godwin, John T. Bailey, John Marston, Jr., Thomas C. Else, James McC Creighton, and Joseph Wright, defendants, to the bill of complaint of the American Bell Telephone Company, and the Bell Telephone Company, complainants, against the Clay Commercial Telephone Company, and others, defendants.

These defendants, now and all times hereafter, saving and reserving unto themselves all and all manner of benefit or advantage of exception which can or may be had or taken to the many errors, un-

certainties, and other imperfections in the said complainants' said bill of complaint contained, nevertheless for answer thereunto, or unto so many and such parts thereof as these defendants are advised is, or are, material or necessary for them to make anwer unto, answering, say: —

That these defendants are directors and officers of the Clay Commercial Telephone Company, one of the defendants in this suit; that they have not, nor has any one of them, to their or his knowledge or belief, violated or infringed the rights of the said complainants in manner and form as alleged and set forth in said bill of complaint; that they are not parties or privies to the alleged acts of the said Clay Commercial Telephone Company, otherwise than as directors and officers of said company; that they have not, by any vote or other act or proceeding, as such directors or officers, authorized or directed the use, or caused or procured the use, by the said Clay Commercial Telephone Company, of telephonic or other devices, which, to the knowledge or belief of these defendants, were infringements or violations of the said patents in said bill mentioned, or of either of them, or of the rights of said complainants thereunder, or which they had cause or reason to know or believe to be so; and that they cannot, as they are advised, by reason of the mere fact of being officers and directors of said company, be properly joined as defendants therewith in a charge of alleged joint infringement as in said bill contained, and can much less be properly joined where, as in said bill, it is not even alleged that they are such officers or directors.

And these respondents, further answering, say that they deny it to be true, as in said bill alleged, that they, well knowing the premises contained and set forth in said bill, have themselves jointly, or have jointly with the said Clay Commercial Telephone Company, or have otherwise, made and used, or furnished to others for use, or sold or caused to be sold, electric speaking telephones constructed and adapted for the transmission of speech, by and according to the method described and claimed by the said Bell in the two several patents in the said bill mentioned, or as claimed by the said complainants in said bill.

Further answering, and subject to the matters aforesaid, these de-

fendants pray that they may, if need be, at the hearing of this cause, or otherwise, avail themselves of, and receive, the benefit and advantage of the answer filed in this suit by the said Clay Commercial Telephone Company, with like effect as if the same were here at large repeated, or as if they had formally joined with said company therein.

Wherefore, by reason of all and singular the matters and things, and the premises aforesaid, these defendants say that they are advised, and they accordingly respectfully submit, that the said complainants are not entitled to any relief as against these defendants; and they humbly pray to be hence dismissed with their reasonable costs and charges in this behalf unjustly incurred.

WM. W. KER,
FURMAN SHEPPARD,
Counsel for said Defendants.

THE SEVERAL ANSWER

Of W. Harrison Godwin, defendant, to the bill of complaint of the American Bell Telephone Company, and the Bell Telephone Company, complainants, against the Clay Commercial Telephone Company, and others, defendants.

This defendant, saving and reserving unto himself all benefit of exception to said bill, and to the defects and insufficiencies thereof, nevertheless for answer saith, that he is a stranger to the matters and things contained in said bill of complaint; that he has not at any time infringed or violated either of the patents in the said bill mentioned, or any of the rights thereunder claimed by the complainants; that he has not, at any time, made, sold or used telephonic devices, as alleged in said bill; and that he is not a director of the said Clay Commercial Telephone Company, or concerned in its proceedings or business, or a party thereto.

Further answering, the defendant saith, that he is employed by said company as its secretary; that his duties as such are merely clerical, being only those which are ordinarily performed by a secre-

tary; that he is not otherwise a participant in the acts or business of said company, or cognizant thereof, or concerned therewith, or responsible therefor; and he submits that by reason thereof the complainants are not entitled to any remedy or relief against him, as alleged in said bill, and that he is improperly joined as a defendant therein.

All of which this defendant is ready and willing to aver, maintain and prove; wherefore he prays to be hence dismissed with his reasonable costs and charges in this behalf unjustly incurred.

WM. W. KER,
FURMAN SHEPPARD,
Counsel for said Defendant.

THE SEVERAL ANSWER

Of Henry Clay, defendant, to the bill of complaint of the American Bell Telephone Company and the Bell Telephone Company, complainants, against the Clay Commercial Telephone Company, and others, defendants.

This defendant, saving and reserving unto himself all benefit and advantage of exception to said bill and to the defects and insufficiencies thereof, nevertheless for answer saith, that he is not, and hath never been, a director or an officer of the said Clay Commercial Telephone Company; that he is the assignor to said company of certain Letters Patent of the United States issued to him, the said Clay, as the first and original inventor thereof, as severally mentioned in the answer of the said company in this suit; that he is engaged in the employment and service of said company for the purpose of keeping and maintaining the telephone instruments of said company in proper working order and repair; that he is not, otherwise than in the way of the regular discharge of the said duties of his said employment and service, a party to, or cognizant of, or a participant in, or responsible for, the acts and proceedings of said company; that he has not, in the discharge of said duties, either jointly with said company as in said bill is alleged, or otherwise,

violated or infringed, to his knowledge or belief, either in act or intent, the said Letters Patent in the said bill mentioned, or either of them, or the rights of the said complainants claimed thereunder; and that by reason of the premises, he is, as he is advised, and as he respectfully submits, improperly joined as a defendant in said bill.

And as respects all and singular the matters and things contained in the answer of the said Clay Commercial Telephone Company in this suit, this defendant prays that he may, if need be, avail himself thereof at the hearing of this cause, or otherwise, with like effect, as if the same were here at length set forth, or as if he had formally joined therein as a party thereto.

Wherefore, and by reason of the premises, this defendant saith that the said complainants are not entitled to recover against him the relief by them claimed in their said bill, or other relief; and he humbly prays to be hence dismissed, with his costs and charges, in this behalf unjustly incurred.

WM. W. KER,
FURMAN SHEPPARD,
Counsel for said Defendant.

THE SEVERAL ANSWER

Of Alonzo P. Douglass, defendant, to the bill of complaint of the American Bell Telephone Company, and the Bell Telephone Company, complainants, against the Clay Commercial Telephone Company, and others, defendants.

This defendant, saving and reserving unto himself all benefit and advantage of exception to the defects and imperfections of said complainants' said bill, nevertheless for answer thereto saith, that he is a stranger to the material and substantial matters and things in said bill contained; that he is not an officer, or a director, of the said Clay Commercial Telephone Company; and that he is not a participant in its business, or a party thereto, or cognizant thereof, or responsible therefor, or in any way entitled to control or direct the same.

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And defendant further saith that he is an attorney-at-law, and is engaged in the practice of his profession; that, as a member of the bar, he has, from time to time, transacted matters of legal business for the said Clay Commercial Telephone Company; that the only relation subsisting between himself and said company is the professional relation of counsel and client; that he has not been otherwise concerned in or connected with the acts or proceedings of said company; and that he has not either jointly with said company, or individually, violated or infringed either of the said Letters Patent in the said bill mentioned, or any rights claimed by the complainants thereunder.

Defendant further saith that in the Certificate of Incorporation of the said Clay Commercial Telephone Company, he is one of the three corporators named; that the stock held by him at that time consisted of the sum of five shares; that he held the same only nominally to facilitate the granting of said certificate; and that within about thirty days after the granting of the same, he parted with said shares, and divested himself of all interest in said company as a corporator therein.

Wherefore, and by reason of the premises, the defendant submits that he has been improperly joined as a party defendant to said bill; and he accordingly prays to be hence dismissed with his reasonable costs and charges in this behalf unjustly sustained.

WILLIAM W. KER,
FURMAN SHEPPARD,
Counsel for said Defendant.

REPLICATION.

[FILED SEPT. 2, 1884.]

The replication of the American Bell Telephone Company and the Bell Telephone Company of Philadelphia, complainants, to the separate answer of the Clay Commercial Telephone Company, the joint and several answer of John C. Scott, James McMillen, George W. Bratton, Samuel P. Godwin, John T. Bailey, John Marston, Jr.,

[ENDORSED.]

CIRCUIT COURT OF THE UNITED STATES.

EASTERN DISTRICT OF PENNSYLVANIA.

IN EQUITY.

April Sessions, 1884. *No.* 15.

AMERICAN BELL TELEPHONE COMPANY ET AL.

v.

THE CLAY COMMERCIAL TELEPHONE COMPANY ET AL.

ANSWER OF DEFENDANTS.

WM. W. KER.

FURMAN SHEPPARD,

Counsel for Defendants.

Filed August 9, 1884.

And afterwards, to wit, on the second day of September, A. D. 1884, the complainants, by their solicitor, Charles Howson, Esq., come into Court here and file their Replication, which being read is as follows, to wit:

(Here follows Replication.)

(Endorsed): C. C. U. S., E. D. of Pa. No. 15—April, 1884. American Bell Telephone Co. et al. *v.* The Clay Commercial Telephone Co. et al.

Replication filed September 2, 1884. C. Howson, Sol'r.

Thomas C. Else, James McC. Creighton, and Joseph Wright, the several answer of W. H. Godwin, and the several answer of Henry Clay, and the several answer of Alonzo P. Douglass, defendants.

These repliants, saving and reserving unto themselves all and all manner of advantage of exception to the manifold insufficiencies of the said several answers and each of them, for replication thereunto, say that they will aver and prove their said bill to be true, certain and sufficient in the law to be answered unto; and that the said several answers of the said defendants, all and each of them, are and is uncertain, untrue, and insufficient to be replied unto by these repliants; without this, that any other matter or thing whatsoever in the said several answers and each of them contained, material or effectual in the law to be replied unto, confessed and avoided, traversed or denied, is true; all which matters and things these repliants are and will be ready to aver and prove, as this Honorable Court shall direct; and humbly pray as in and by their said bill they have already prayed.

CHARLES HOWSON,
Solicitor and Counsel for Complainants.

EVIDENCE FOR COMPLAINANTS.

TAKEN PURSUANT TO THE SIXTY-SEVENTH RULE OF THE SUPREME COURT OF THE UNITED STATES, IN EQUITY, AS AMENDED, BEFORE ME,

CHARLES H. SWAN, *Special Examiner.*

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95 MILK STREET, BOSTON, MASS., Nov. 20, 1884.

Present: GEORGE L. ROBERTS, Esq., *of Counsel for Complainants;*
FURMAN SHEPPARD, Esq., *of Counsel for Defendants.*

Counsel for complainants puts in evidence: —

1. Certified copy of Letters Patent No. 174,465, granted Alexander Graham Bell, March 7, 1876, which is marked "Exhibit Bell Patent, No. 174,465, Chas. H. Swan, Special Examiner."

2. Certified copy of Letters Patent No. 186,787, granted Alexander Graham Bell, Jan. 30, 1877, which is marked "Exhibit Bell Patent No. 186,787, Chas. H. Swan, Special Examiner."

3. Certified copies of the following assignments: —

A. Alexander Graham Bell to Gardiner G. Hubbard, trustee, dated July , 1877, and recorded July 28, 1877, Liber R^{21}, page 399.

B. Gardiner G. Hubbard, trustee, to the Bell Telephone Company, dated July 20, 1878, and recorded Oct. 3, 1878, Liber Y^{22}, page 460.

C. Bell Telephone Company to American Bell Telephone Company, dated June 22, 1880, and recorded June 24, 1880, Liber I^{25}, page 282; and the same are marked "Exhibit Assignments, Chas. H. Swan, Special Examiner."

4. Certified copy of the charter of the American Bell Telephone Company, and also certified copy of the certificate of incorporation of the American Bell Telephone Company, and the same are marked "Exhibit Complainants' Incorporation, Chas. H. Swan, Special Examiner."

[*Defendants' counsel objects to the several assignments and the charter and certificate of incorporation, as not disclosing or proving the title set forth in the bill, or other sufficient title to maintain this suit.*]

Said documentary evidence is as follows: —

UNITED STATES PATENT OFFICE.

ALEXANDER GRAHAM BELL, OF SALEM, MASSACHUSETTS.

IMPROVEMENT IN TELEGRAPHY.

Specification forming part of Letters Patent No. 174,465, dated March 7, 1876; application filed Febuary 14, 1876.

To all whom it may concern:

Be it known that I, ALEXANDER GRAHAM BELL, of Salem, Massachusetts, have invented certain new and useful Improvements in Telegraphy, of which the following is a specification: —

In Letters Patent granted to me April 6, 1875, No. 161,739, I have described a method of, and apparatus for, transmitting two or more telegraphic signals simultaneously along a single wire by the employment of transmitting instruments, each of which occasions a succession of electrical impulses differing in rate from the others; and of receiving instruments, each tuned to a pitch at which it will be put in vibration to produce its fundamental note by one only of the transmitting instruments; and of vibratory circuit-breakers operating to convert the vibratory movement of the receiving instrument into a permanent make or break (as the case may be) of a local circuit, in which is placed a Morse sounder, register, or other telegraphic apparatus. I have also therein described a form of autograph-telegraph based upon the action of the above-mentioned instruments.

In illustration of my method of multiple telegraphy I have shown in the patent aforesaid, as one form of transmitting instrument, an electro-magnet having a steel-spring armature, which is kept in vibration by the action of a local battery. This armature in vibrating makes and breaks the main circuit, producing an intermittent current upon the line-wire. I have found, however, that upon this plan the limit to the number of signals that can be sent simultaneously over the same wire is very speedily reached; for, when a number of transmitting instruments, having different rates of vibration, are simultaneously making and breaking the same circuit, the

effect upon the main line is practically equivalent to one continuous current.

In a pending application for Letters Patent, filed in the United States Patent Office Feburary 25, 1875, I have described two ways of producing the intermittent current — the one by actual make and break of contact, the other by alternately increasing and diminishing the intensity of the current without actually breaking the circuit. The current produced by the latter method I shall term, for distinction sake, a pulsatory current.

My present invention consists in the employment of a vibratory or undulatory current of electricity in contradistinction to a merely intermittent or pulsatory current, and of a method of, and apparatus for, producing electrical undulations upon the line-wire.

The distinction between an undulatory and a pulsatory current will be understood by considering that electrical pulsations are caused by sudden or instantaneous changes of intensity, and that electrical undulations result from gradual changes of intensity exactly analogous to the changes in the density of air occasioned by simple pendulous vibrations. The electrical movement, like the aerial motion, can be represented by a sinusoidal curve or by the resultant of several sinusoidal curves.

Intermittent or pulsatory and undulatory currents may be of two kinds, accordingly as the successive impulses have all the same polarity or are alternately positive and negative.

The advantages I claim to derive from the use of an undulatory current in place of a merely intermittent one are, first, that a very much larger number of signals can be transmitted simultaneously on the same circuit; second, that a closed circuit and single main battery may be used; third, that communication in both directions is established without the necessity of special induction-coils; fourth, that cable despatches may be transmitted more rapidly than by means of an intermittent current or by the methods at present in use; for, as it is unnecessary to discharge the cable before a new signal can be made, the lagging of cable-signals is prevented; fifth, and that as the circuit is never broken a spark-arrester becomes unnecessary.

It has long been known that when a permanent magnet is caused

to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter, and that when it is made to recede a current of opposite polarity to the first appears upon the wire. When, therefore, a permanent magnet is caused to vibrate in front of the pole of an electro-magnet an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond, in rapidity of succession, to the vibrations of the magnet, in polarity to the direction of its motion, and in intensity to the amplitude of its vibration.

That the difference between an undulatory and an intermittent current may be more clearly understood I shall describe the condition of the electrical current when the attempt is made to transmit two musical notes simultaneously — first upon the one plan and then upon the other. Let the interval between the two sounds be a major third; then their rates of vibration are in the ratio of 4 to 5. Now, when the intermittent current is used the circuit is made and broken four times by one transmitting instrument in the same time that five makes and breaks are caused by the other. A and B, Figs. 1, 2, and 3, represent the intermittent currents produced, four impulses of B being made in the same time as five impulses of A. *c c c*, &c., show where and for how long time the circuit is made, and *d d d*, &c., indicate the duration of the breaks of the circuit. The line A and B shows the total effect upon the current when the transmitting instruments for A and B are caused simultaneously to make and break the same circuit. The resultant effect depends very much upon the duration of the make relatively to the break. In Fig. 1 the ratio is as 1 to 4; in Fig. 2, as 1 to 2; and in Fig. 3 the makes and breaks are of equal duration. The combined effect, A and B, Fig. 3, is very nearly equivalent to a continuous current.

When many transmitting instruments of different rates of vibration are simultaneously making and breaking the same circuit the current upon the main line becomes for all practical purposes continuous.

Next, consider the effect when an undulatory current is employed. Electrical undulations, induced by the vibration of a body capable of inductive action, can be represented graphically, without error, by the same sinusoidal curve which expresses the vibration of the

inducing body itself, and the effect of its vibration upon the air; for, as above stated, the rate of oscillation in the electrical current corresponds to the rate of vibration of the including body — that is, to the pitch of the sound produced. The intensity of the current varies with the amplitude of the vibration — that is, with the loudness of the sound; and the polarity of the current corresponds to the direction of the vibrating body — that is, to the condensations and rarefactions of air produced by the vibration. Hence, the sinusoidal curve A or B, Fig. 4, represents, graphically, the electrical undulations induced in a circuit by the vibration of a body capable of inductive action.

The horizontal line *a d e f*, &c., represents the zero of current. The elevations *b b b*, &c., indicate impulses of positive electricity. The depressions *c c c*, &c., show impulses of negative electricity. The vertical distance *b d* or *c f* of any portion of the curve from the zero-line expresses the intensity of the positive or negative impulse at the part observed, and the horizontal distance *a a* indicates the duration of the electrical oscillation. The vibrations represented by the sinusoidal curves B and A, Fig. 4, are in the ratio aforesaid, of 4 to 5 — that is, four oscillations of B are made in the same time as five oscillations of A.

The combined effect of A and B, when induced simultaneously on the same circuit, is expressed by the curve A+B, Fig. 4, which is the algebraical sum of the sinusoidal curves A and B. This curve A+B also indicates the actual motion of the air when the two musical notes considered are sounded simultaneously. Thus, when electrical undulations of different rates are simultaneously induced in the same circuit, an effect is produced exactly analogous to that occasioned in the air by the vibration of the inducing bodies. Hence, the co-existence upon a telegraphic circuit of electrical vibrations of different pitch is manifested, not by the obliteration of the vibratory character of the current, but by peculiarities in the shapes of the electrical undulations, or, in other words, by peculiarities in the shapes of the curves which represent those undulations.

There are many ways of producing undulatory currents of electricity, dependent for effect upon the vibrations or motions of bodies capable of inductive action. A few of the methods that may be

employed I shall here specify. When a wire, through which a continuous current of electricity is passing, is caused to vibrate in the neighborhood of another wire, an undulatory current of electricity is induced in the latter. When a cylinder, upon which are arranged bar-magnets, is made to rotate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet.

Undulations are caused in a continuous voltaic current by the vibration or motion of bodies capable of inductive action; or by the vibration of the conducting-wire itself in the neighborhood of such bodies. Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery. The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current. The external resistance may also be varied. For instance, let mercury or some other liquid form part of a voltaic circuit, then the more deeply the conducting-wire is immersed in the mercury or other liquid, the less resistance does the liquid offer to the passage of the current. Hence, the vibration of the conducting-wire in mercury or other liquid included in the circuit occasions undulations in the current. The vertical vibrations of the elements of a battery in the liquid in which they are immersed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery.

In illustration of the method of creating electrical undulations, I shall show and describe one form of apparatus for producing the effect. I prefer to employ for this purpose an electro-magnet, A, Fig. 5, having a coil upon only one of its legs *b*. A steel-spring armature, *c*, is firmly clamped by one extremity to the uncovered leg *d* of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature *c* can be set in vibration in a variety of ways, one of which is by wind, and, in vibrating, it produces a musical note of a certain definite pitch.

When the instrument A is placed in a voltaic circuit, *g b e f g*,

the armature *c* becomes magnetic, and the polarity of its free end is opposed to that of the magnet underneath. So long as the armature *c* remains at rest, no effect is produced upon the voltaic current, but the moment it is set in vibration to produce its musical note a powerful inductive action takes place, and electrical undulations traverse the circuit *g b e f g*. The vibratory current passing through the coil of the electro-magnet *f* causes vibration in its armature *h* when the armature *c h* of the two instruments A I are normally in unison with one another; but the armature *h* is unaffected by the passage of the undulatory current when the pitches of the two instruments are different.

A number of instruments may be placed upon a telegraphic circuit, as in Fig. 6. When the armature of any one of the instruments is set in vibration all the other instruments upon the circuit which are in unison with it respond, but those which have normally a different rate of vibration remain silent. Thus, if A, Fig. 6, is set in vibration, the armatures of A^1 and A^2 will vibrate also, but all the others on the circuit will remain still. So if B^1 is caused to emit its musical note the instruments B B^2 respond. They continue sounding so long as the mechanical vibration of B^1 is continued, but become silent with the cessation of its motion. The duration of the sound may be used to indicate the dot or dash of the Morse alphabet, and thus a telegraphic dispatch may be indicated by alternately interrupting and renewing the sound. When two or more instruments of different pitch are simultaneously caused to vibrate, all the instruments of corresponding pitches upon the circuit are set in vibration, each responding to that one only of the transmitting instruments with which it is in unison. Thus the signals of A, Fig. 6, are repeated by A^1 and A^2, but by no other instrument upon the circuit; the signals of B^2 by B and B^1; and the signals of C^1 by C and C^2 — whether A, B^2, and C^1 are successively or simultaneously caused to vibrate. Hence by these instruments two or more telegraphic signals or messages may be sent simultaneously over the same circuit without interfering with one another.

I desire here to remark that there are many other uses to which these instruments may be put, such as the simultaneous transmission

of musical notes, differing in loudness as well as in pitch, and the telegraphic transmission of noises or sounds of any kind.

When the armature *c*, Fig. 5, is set in vibration the armature *h* responds not only in pitch but in loudness. Thus, when *c* vibrates with little amplitude, a very soft musical note proceeds from *h*; and when *c* vibrates forcibly the amplitude of the vibration of *h* is considerably increased, and the resulting sound becomes louder. So, if A and B, Fig. 6, are sounded simultaneously, (A loudly and B softly,) the instruments A^1 and A^2 repeat loudly the signals of A, and B^1 B^2 repeat softly those of B.

One of the ways in which the armature *c*, Fig. 5, may be set in vibration has been stated above to be by wind. Another mode is shown in Fig. 7, whereby motion can be imparted to the armature by the human voice or by means of a musical instrument.

The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane, *a*. A cone, A, is used to converge sound-vibrations upon the membrane. When a sound is uttered in the cone the membrane *a* is set in vibration, the armature *c* is forced to partake of the motion, and thus electrical undulations are created upon the circuit E *b e f g*. These undulations are similar in form to the air vibrations caused by the sound — that is, they are represented graphically by similar curves. The undulatory current passing through the electro-magnet *f* influences its armature *h* to copy the motion of the armature *c*. A similar sound to that uttered into A is then heard to proceed from L.

In this specification the three words "oscillation," "vibration," and "undulation," are used synonymously, and in contradistinction to the terms "intermittent" and "pulsatory." By the term "body capable of inductive action," I mean a body which, when in motion, produces dynamical electricity. I include in the category of bodies capable of inductive action — brass, copper, and other metals, as well as iron and steel.

Having described my invention, what I claim, and desire to secure by Letters Patent, is as follows:

1. A system of telegraphy in which the receiver is set in vibra-

tion by the employment of undulatory currents of electricity, substantially as set forth.

2. The combination, substantially as set forth, of a permanent magnet or other body capable of inductive action, with a closed circuit, so that the vibration of the one shall occasion electrical undulations in the other, or in itself, and this I claim, whether the permanent magnet be set in vibration in the neighborhood of the conducting-wire forming the circuit, or whether the conducting-wire be set in vibration in the neighborhood of the permanent magnet, or whether the conducting-wire and the permanent magnet both simultaneously be set in vibration in each other's neighborhood.

3. The method of producing undulations in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration or motion of the conducting-wire itself, in the neighborhood of such bodies, as set forth.

4. The method of producing undulations in a continuous voltaic circuit by gradually increasing and diminishing the resistance of the circuit, or by gradually increasing and diminishing the power of the battery, as set forth.

5. The method of, and apparatus for, transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth.

In testimony whereof I have hereunto signed my name this 20th day of January, A. D. 1876.

ALEX. GRAHAM BELL.

Witnesses:

THOMAS E. BARRY,

P. D. RICHARDS.

2 Sheets—Sheet 1.

A. G. BELL.

TELEGRAPHY.

No. 174,465. Patented March 7, 1876.

Fig. 1.

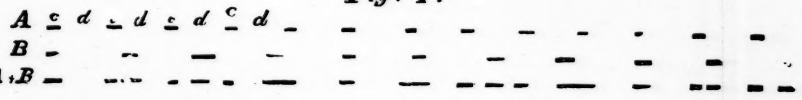


Fig. 2.

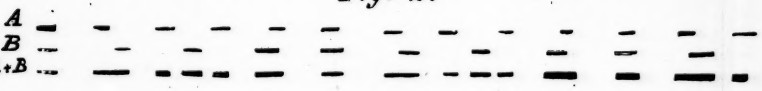


Fig. 3

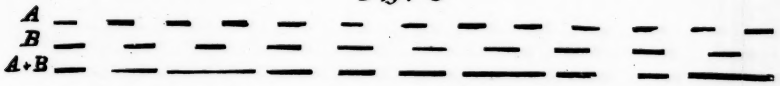


Fig. 4.

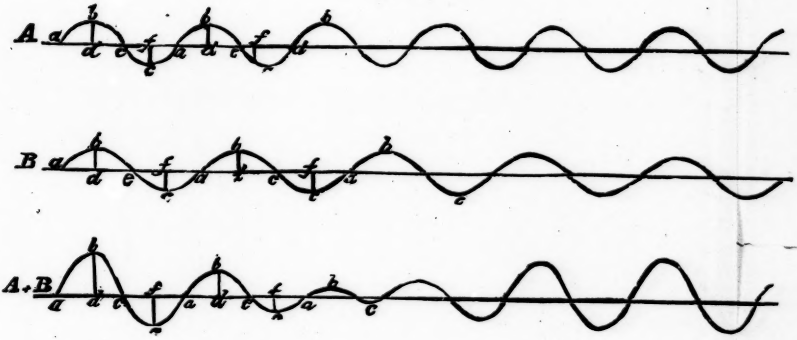
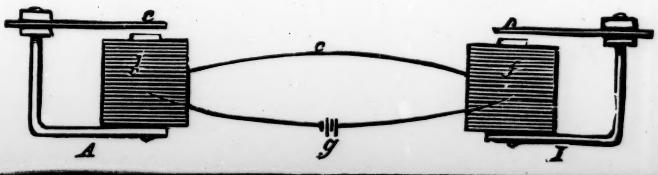


Fig. 5.



2 Sheets—Sheet 2

66

A. G. BELL.

TELEGRAPHY

No. 174,465. Patented March 7, 1876.

Fig. 6.

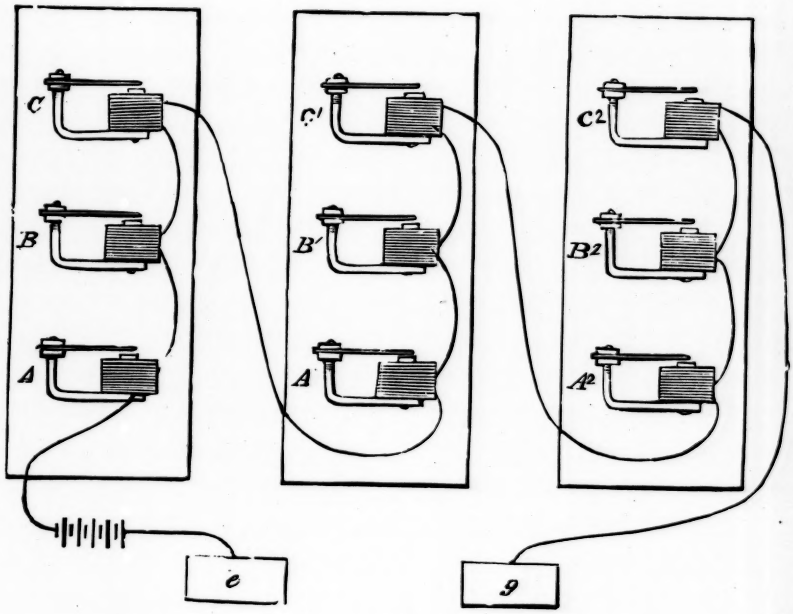
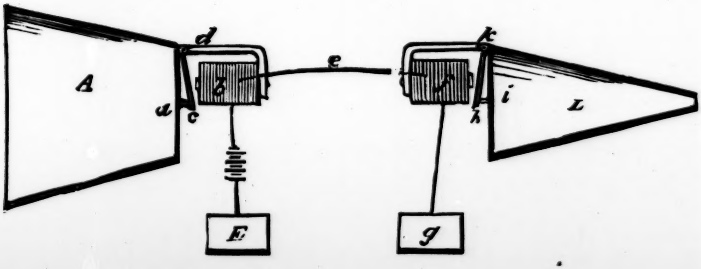


Fig. 7



UNITED STATES PATENT OFFICE.

ALEXANDER GRAHAM BELL, OF BOSTON, MASSACHUSETTS.

IMPROVEMENT IN ELECTRIC TELEGRAPHY.

Specification forming part of Letters Patent No. 186,787, dated January 30, 1877; application filed January 15, 1877.

To all whom it may concern:

Be it known that I, ALEXANDER GRAHAM BELL, of Boston, Massachusetts, have invented certain new and useful Improvements in Electric Telephony, of which the following is a specification:

In Letters Patent granted to me the 6th day of April, 1875, No. 161,739, and in an application for Letters Patent of the United States now pending, I have described a method of and apparatus for producing musical tones by the action of a rapidly-interrupted electrical current, whereby a number of telegraphic signals can be sent simultaneously along a single circuit.

In another application for Letters Patent now pending in the United States Patent Office I have described a method of and apparatus for inducing an intermittent current of electricity upon a line-wire, whereby musical tones can be produced and a number of telegraphic signals be sent simultaneously over the same circuit, in either or in both directions; and in Letters Patent granted to me March 7, 1876, No. 174,465, I have shown and described a method of an apparatus for producing musical tones by the action of undulatory currents of electricity, whereby a number of telegraphic signals can be sent simultaneously over the same circuit, in either or in both directions, and a single battery be used for the whole circuit.

In the applications and patents above referred to, signals are transmitted simultaneously along a single wire by the employment of transmitting-instruments, each of which occasions a succession of electrical impulses differing in rate from the others, and are received without confusion by means of receiving-instruments, each tuned to

a pitch at which it will be put in vibration to produce its fundamental note by one only of the transmitting-instruments. A separate instrument is therefore employed for every pitch, each instrument being capable of transmitting or receiving but a single note, and thus as many separate instruments are required as there are messages or musical notes to be transmitted.

My invention has for its object, first, the transmission simultaneously of two or more musical notes or telegraphic signals along a single wire in either or both directions, and with a single battery for the whole circuit without the use of as many instruments as there are musical notes or telegraphic signals to be transmitted; second, the electrical transmission by the same means of articulate speech and sound of every kind, whether musical or not; third, the electrical transmission of musical tones, articulate speech, or sounds of every kind, without the necessity of using a voltaic battery.

In my Patent No. 174,465, dated March 7, 1876, I have shown as one form of transmitting-instrument a stretched membrane, to which the armature of an electro-magnet is attached, whereby motion can be imparted to the armature by the human voice, or by means of a musical instrument, or by sounds produced in any way.

In accordance with my present invention I substitute for the membrane and armature shown in the transmitting and receiving instruments alluded to above a plate of iron or steel capable of being thrown into vibration by sounds made in its neighborhood.

The nature of my invention and the manner in which the same is or may be carried into effect will be understood by reference to the accompanying drawings, in which —

Figure 1 is a perspective view of one form of my electric telephone. Fig. 2 is a vertical section of the same, and Fig. 3 is a plan view of the apparatus. Fig. 4 is a diagram illustrating the arrangement upon circuit.

Similar letters in the drawings represent corresponding portions of the apparatus.

A in said drawings represents a plate of iron or steel, which is fastened at B and C to the cover or sounding-box D. E represents a speaking-tube, by which sounds may be conveyed to or from the

plate A. F is a bar of soft iron. G is a coil of insulated copper wire, placed around the extremity of the end H of the bar F. I is an adjusting-screw, whereby the distance of the end H from the plate A may be regulated.

The electric telephones J, K, L, and M are placed at different stations upon a line, and are arranged upon circuit with a battery, N, as shown in diagram, Fig. 4.

I have shown the apparatus in one of its simplest forms, it being well understood that the same may be varied in arrangement, combination, general construction, and form, as well as material of which the several parts are composed.

The operation and use of this instrument are as follows:

I would premise by saying that this instrument is and may be used both as a transmitter and as a receiver — that is to say, the sender of the message will use an instrument in every particular identical in construction and operation with that employed by the receiver, so that the same instrument can be used alternately as a receiver and a transmitter.

In order to transmit a telegraphic message by means of these instruments, it is only necessary for the operator at a telephone (say J) to make a musical sound in any way in the neighborhood of the plate A — for convenience of operation, through the speaking-tube E — and to let the duration of the sound signify the dot or dash of the Morse alphabet, and for the operator who receives his message (say at M) to listen to his telephone, preferably through the speaking-tube E. When two or more musical signals are being transmitted over the same circuit all the telephones reproduce the signals for all the messages; but as the signals for each message differ in pitch from those for the other messages, it is easy for an operator to fix his attention upon one message and ignore the other.

When a large number of despatches are being simultaneously transmitted it will be advisable for the operator to listen to his telephone through a resonator, which will re-enforce to his ear the signals which he desires to observe. In this way he is enabled to direct his attention to the signals for any given message without

being distracted or disturbed by the signals for any other messages that may be passing over the line at the time.

The musical signals, if preferred, can be automatically received by means of a resonator, one end of which is closed by a membrane, which vibrates only when the note with which the resonator is in unison is emitted by the receiving-telephone. The vibrations of the membrane may be made to operate a circuit-breaker, which will actuate a Morse sounder or a telegraphic recording or registering apparatus.

One form of vibratory circuit-breaker which may be used for this purpose I have described in Letters Patent No. 178,399, June 6, 1876. Hence by this plan the simultaneous transmission of a number of telegraphic messages over a single circuit in the same or in both directions with a single main battery for the whole circuit and a single telephone at each station is rendered practicable. This is of great advantage in this, that for the conveyance of several messages, or signals, or sounds over a single wire simultaneously, it is no longer necessary to have separate instruments correspondingly tuned for each given sound, which plan requires nice adjustment of the corresponding instruments, while the present improvement admits of a single instrument at each station, or, if for convenience several are employed, they all are alike in construction, and need not be adjusted or tuned to particular pitches.

Whatever sound is made in the neighborhood of any telephone — say at J, Fig. 4 — is echoed in fac-simile by the telephones of all the other stations upon the circuit; hence this plan is also adapted for the use of the transmitting intelligibly the exact sounds of articulate speech. To convey an articulate message it is only necessary for an operator to speak in the neighborhood of his telephone, preferably through the tube E, and for another operator at a distant station upon the same circuit to listen to the telephone at that station. If two persons speak simultaneously in the neighborhood of the same or different telephones, the utterances of the two speakers are reproduced simultaneously by all the other telephones on the same circuit; hence by this plan a number of vocal messages may be transmitted simultaneously on the same circuit, in either or both directions. All the effects noted above may be produced by the

same instruments without a battery by rendering the central bar F H permanently magnetic. Another form of telephone for use without a battery is shown in Fig. 5, in which O is a compound permanent magnet, to the poles of which are affixed poll-pieces of soft iron, P Q, surrounded by helices of insulated wire R S.

Fig. 6 illustrates the arrangement upon circuits of similar instruments to that shown in Fig. 5.

In lieu of the plate A in above figures, iron or steel reeds of definite pitch may be placed in front of the electro-magnet O, and, in connection with a series of such instruments of different pitches, an arrangement upon circuit may be employed similar to that shown in my Patent No. 174,465, and illustrated in Fig. 6 of Sheet 2 in said patent. The battery, of course, may be omitted.

This invention is not limited to the use of iron or steel, but includes within its scope any material capable of inductive action.

The essential feature of the invention consists in the armature of the receiving-instrument being vibrated by the varying attraction of the electro-magnet so as to vibrate the air in the vicinity thereof in the same manner as the air is vibrated at the other end by the production of the sound. It is, therefore, by no means necessary or essential that the transmitting-instrument should be of the same construction as the receiving-instrument. Any instrument receiving and transmitting the impression of agitated air may be used as the transmitter, although, for convenience and for reciprocal communication, I prefer to use like instruments at either end of an electrical wire. I have heretofore described and exhibited such other means of transmitting sound, as will be seen by reference to the proceedings of the American Academy of Arts and Sciences, Volume XII.

For convenience, I prefer to apply to each instrument a call-bell. This may be arranged so as to ring, first, when the main circuit is opened; second, when the bar F comes into contact with the plate A. The first is done to call attention; the second indicates when it is necessary to readjust the magnet, for it is important that the distance of the magnet from the plate should be as little as possible, without, however, being in contact. I have also found that the electrical undulations produced upon the main line by the vibration of the plate A are intensified by placing the coil G at the end of the

bar F nearest the plate A, and not extend it beyond the middle, or thereabout.

Having thus described my invention, what I claim, and desire to secure by Letters Patent, is —

1. The union upon, and by means of, an electric circuit of two or more instruments, constructed for operation substantially as herein shown and described, so that, if motion of any kind or form be produced in any way in the armature of any one of the said instruments, the armatures of all the other instruments upon the same circuit will be moved in like manner and form, and if such motion be produced in the former by sound, like sound will be produced by the motion of the latter.

2. In a system of electric telegraphy or telephony, consisting of transmitting and receiving instruments united upon an electric circuit, the production, in the armature of each receiving-instrument, of any given motion by subjecting said armature to an attraction varying in intensity, however such variation may be produced in the magnet; and hence I claim the production of any given sound or sounds from the armature of the receiving-instrument by subjecting said armature to an attraction varying in intensity, in such manner as to throw the armature into that form of vibration that characterizes the given sound or sounds.

3. The combination, with an electro-magnet, of a plate of iron or steel, or other material capable of inductive action, which can be thrown into vibration by the movement of surrounding air or by the attraction of a magnet.

4. In combination with a plate and electro magnet, as before claimed, the means herein described, or their mechanical equivalents, of adjusting the relative position of the two so that, without touching, they may be set as closely together as possible.

5. The formation, in an electric telephone such as herein shown and described, of a magnet with a coil upon the end or ends of the magnet nearest the plate.

6. The combination, with an electric telephone such as described, of a sounding-box, substantially as herein shown and set forth.

7. In combination with an electric telephone, as herein described,

the employment of a speaking or hearing tube for conveying sounds to or from the telephone, substantially as set forth.

8. In a system of electric telephony, the combination of a permanent magnet with a plate of iron or steel, or other material capable of inductive action, with coils upon the end or ends of said magnet nearest the plate, substantially as set forth.

In testimony whereof I have hereunto signed my name this 13th day of January, A. D. 1877.

A. GRAHAM BELL.

Witnesses:

HENRY R. ELLIOTT,

EWELL A. DICK.

2 Sheets—Sheet 1.

A. G. BELL.

ELECTRIC TELEGRAPHY.

No. 186,787. Patented Jan. 30, 1877.

Fig. 1.

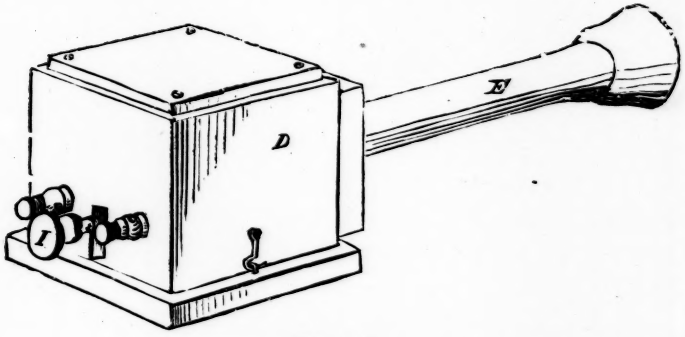


Fig. 2.

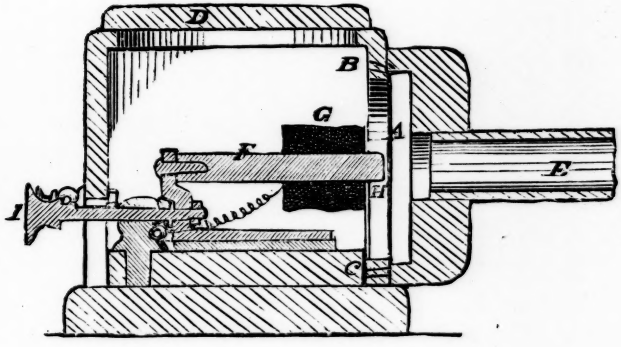
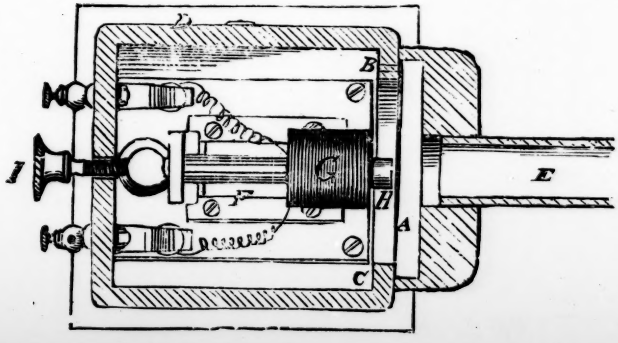


Fig. 3.



Attest:

A. G. BELL.

ELECTRIC TELEGRAPHY.

No. 186,787. Patented Jan. 30, 1877.

Fig. 4.

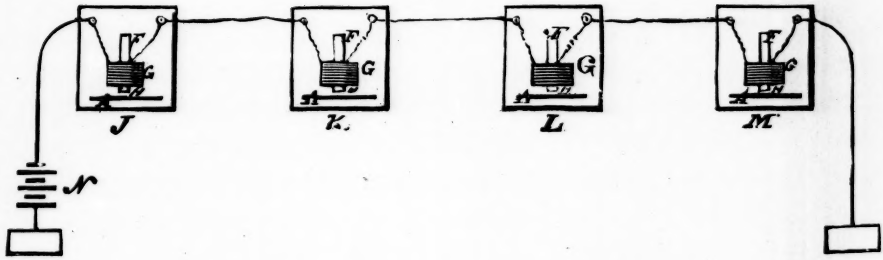


Fig 5.

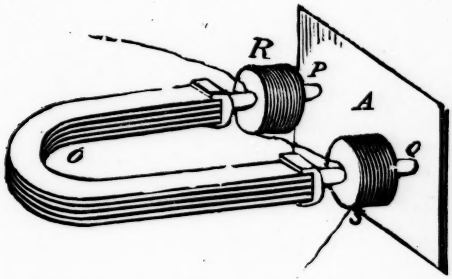
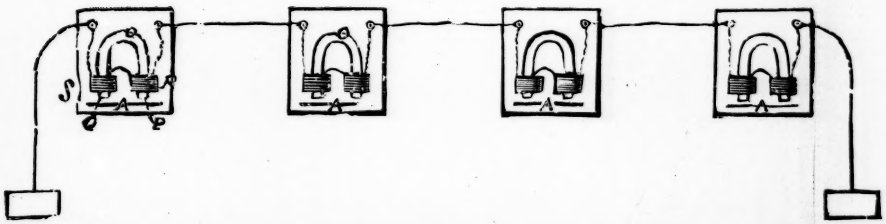


Fig. 6.



Attest:

Inventor:

EXHIBIT ASSIGNMENTS, CHAS. H. SWAN, SPECIAL EXAMINER.

BELL TO HUBBARD.

[R21, p. 399.]

To all whom it may concern: —

Whereas, Alexander Graham Bell, of Boston, in the county of Suffolk and State of Massachusetts, did obtain three several Letters Patent of the United States for an improved system of telegraphy, telephony and telephonic apparatus, which Letters Patent bear date respectively, March seventh, A. D. eighteen hundred and seventy-six, and numbered 174,465; June sixth, A. D. eighteen hundred and seventy-six, and numbered 178,399; and January thirtieth, A. D. eighteen hundred and seventy-seven, and numbered 186,787.

And whereas Gardiner G. Hubbard, of Cambridge, in the County of Middlesex and State of Massachusetts, Trustee, is desirous of acquiring an interest therein: Now this Indenture witnesseth that for a valuable consideration, viz., one dollar, and other valuable consideration to me in hand paid, the receipt of which is hereby acknowledged, I have assigned, sold and set over, and by these presents do assign, sell and set over unto the said Gardiner G. Hubbard, Trustee, all the right, title and interest I have in the above-described invention, as secured to me by Letters Patent, for, to and in the United States and Territories, and in no other place or places. The same to be held and enjoyed by the said Gardiner G. Hubbard, Trustee, for his own use and behoof, and for the use and behoof of his legal representatives, to the full end of the term for which said Letters were granted, as fully and entirely as the same would have been held and enjoyed by me had this assignment and sale not been made.

In testimony whereof, I have hereunto set my hand and affixed my seal this day of July, in the year of our Lord one thousand eight hundred and seventy-seven.

ALEXANDER GRAHAM BELL. [SEAL]

Sealed and delivered in presence of
CHAS. EUSTIS HUBBARD.

[Recorded July 28, 1877.]

HUBBARD TO BELL TELEPHONE COMPANY.

[Y[22], p. 460.]

To all whom it may concern:

Whereas, Alexander Graham Bell, of Salem, Massachusetts, as assignor to himself, Thomas Sanders and Gardiner G. Hubbard, did obtain Letters Patent of the United States, bearing date April 6th, 1875, and numbered 161,739; and whereas said Alexander Graham Bell did obtain Letters Patent of the United States, bearing date March 7th, 1876, and numbered 174,465; bearing date June 6th, 1876, and numbered 178,399; and bearing date January 30th, 1877, and numbered 186,787, all of said Letters Patent being for improvements in "Telegraphy, Telephony and Telephonic Apparatus," invented by said Alexander Graham Bell; and whereas all of said Letters Patent have been assigned to Gardiner G. Hubbard, trustee, said Letters numbered 161,739, by deed of assignment, delivered July 9th, 1877, and recorded in Liber T[21], page 448 of Transfers of Patents; and said Letters numbered 174,465, 178,399 and 186,787, by deed of assignment, delivered July 9th, 1877, and recorded in Liber R[21], page 399 of Transfers of Patents; and said Hubbard, trustee, is now the owner of the above-described inventions secured by said Letters Patents; and whereas, the Bell Telephone Company, a corporation duly established under the laws of the Commonwealth of Massachusetts, and located at Boston, is desirous of acquiring the ownership of said inventions secured by said Letters Patent: —

Now, this Indenture witnesseth that I, Gardiner G. Hubbard, trustee, in consideration of one dollar and other valuable consideration to me in hand paid by said Bell Telephone Company, the receipt whereof is hereby acknowledged, have assigned, sold and set over, and by these presents do assign, sell and set over unto the said Bell Telephone Company, all my right, title and interest in the above-described inventions and in and to said Letters Patent, each and all of them, the same to be held and enjoyed by the said Bell Telephone Company for its own use and behoof, and for the use and behoof of its legal representatives to the full end of the term for which said Letters were granted, and any extension or reissue thereof as fully

and entirely as the same would have been held and enjoyed by me had this assignment and sale not been made.

In testimony whereof, I have hereunto set my hand and seal this twentieth day of July, in the year eighteen hundred and seventy-eight, being thereto duly authorized.

GARDINER G. HUBBARD, *Trustee.* [SEAL]

In presence of
C. E. HUBBARD.
R. W. DEVONSHIRE.
[Recorded Oct. 3, 1878.]

BELL TELEPHONE CO. TO AMERICAN BELL TELEPHONE CO. [I[25], p. 282.]

Know all men by these presents, That the Bell Telephone Company, a corporation established under the laws of the Commonwealth of Massachusetts, in consideration of one dollar to it paid by the American Bell Telephone Company, a corporation established under the laws of said Commonwealth, the receipt whereof is hereby acknowledged, does hereby grant and convey unto said American Bell Telephone Company the exclusive right under the following patents to all the territory of the United States, except the State of Massachusetts; viz., Letters Patent No. 174,465, issued March 7, 1876, to Alexander Graham Bell for an improvement in telegraphy, and Letters Patent No. 186,787, issued January 30, 1877, to said Alexander Graham Bell for an improvement in electric telegraphy and in and to the inventions therein described or intended to be described.

To have and to hold the same to the said American Bell Telephone Company, its successors and assigns, to their own use and behoof forever.

This instrument is made at the request of the National Bell Telephone Company in pursuance of an agreement between said Bell Telephone Company and said National Bell Telephone Company, dated March 20, 1879, said American Bell Telephone Company being the appointees of said National Bell Telephone Company to receive this conveyance, and in pursuance of an agreement between

said National Bell Telephone Company and said American Bell Telephone Company, dated May 8, 1880.

In witness whereof, said Bell Telephone Company has caused its corporate seal to be hereto affixed and these presents to be signed in its name and behalf by William H. Forbes, its president, and William R. Driver, its treasurer, thereto duly authorized, this twenty-second day of June, A. D. 1880.

[Seal of B. T. Co.] THE BELL TELEPHONE COMPANY,

By W. H. FORBES, *President*,
WM. R. DRIVER, *Treasurer*.

Voted,— That the president and Treasurer be and they hereby are authorized and empowered in the name and on behalf of this Company, to assign and transfer the patents No. 174,465, dated March 7 1876, and No. 186,787, dated January 30. 1877 or any territorial or other interest in them to such assignee as the National Bell Telephone Company may request, in accordance with the agreement with said National Bell Telephone Company dated March 20. 1879 and in pursuance of the vote passed at the Stockholders' meeting held February 20. 1879 authorizing the president and treasurer to convey all the property of this company to the National Bell Telephone Company, such assignment and transfer to be made at such times and in such manner and for such territory as said assignee may desire.

A true copy of vote passed at a stockholders' meeting of The Bell Telephone Company, duly held at Boston, Mass., June 21, 1880

Attest:

[BELL TELEPHONE CO. Incorporated 1878.] CHAS. EUSTIS HUBBARD,
Clerk of The Bell Telephone Co.

[Recorded June 24, 1880.]

EXHIBIT COMPLAINANTS' INCORPORATION.

Chapter 117.

COMMONWEALTH OF MASSACHUSETTS.

IN THE YEAR ONE THOUSAND EIGHT HUNDRED AND EIGHTY.

AN ACT to Incorporate the American Bell Telephone Company. Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows: —

SECTION 1. Alexander Graham Bell, William H. Forbes, George Z. Silsbee, Richard S. Fay, Alexander Cochrane, George L. Bradley, Francis Blake, Jr., Thomas Sanders, and Charles Eustis Hubbard, and their associates, may associate themselves and organize a corporation, according to the provisions of chapter two hundred and twenty-four of the acts of the year eighteen hundred and seventy, and the acts in amendment thereof and addition thereto, for the purpose of manufacturing, owning, selling, using, and licensing others to use electric speaking telephones and other apparatus and appliances pertaining to the transmission of intelligence by electricity, and for that purpose constructing and maintaining by itself and its licensees public and private lines and district exchanges, with a capital stock exceeding one million of dollars, and not exceeding ten millions of dollars.

SECTION 2. For the purposes aforesaid, said corporation may become a stockholder in, or become interested with other corporations hereafter organized for like purposes, or already established for the transaction of telephonic business under its patents and no others: provided, that said corporation shall not become a stockholder in any other corporation doing business in this State to an amount exceeding thirty per cent of the capital stock of said last-named corporation. And it and its licensees may, within this Commonwealth, enjoy the rights given by chapter sixty-four of the General Statutes and Acts amendatory thereof, and shall be subject to the liabilities therein imposed; but section ten of said chapter shall only apply to their public lines; and the apportionment provided by section five of chapter two hundred and eighty-three of the acts of the year eighteen hundred and sixty-five, and acts amendatory thereof, shall be made upon the number of telephones in use by it, or under its authority, or with its permission, or under Letters Patent owned or controlled by it, within and without this Commonwealth, respectively; and the returns to be made under said act shall state the facts required for such apportionment in such form as the tax commissioner may determine; and it shall be the duty of said tax commissioner or his deputy to annually examine the books, accounts and papers of said corporation, so far as may be necessary for the verification of said returns.

SECTION 3. When an injury is done to a person or to property by

the posts, wires, telephones or other apparatus of the corporation, caused by any negligence on the part of itself or its officers, or on the part of any of its agents, servants, employés or operatives, the corporation shall be responsible in damages to the party injured.

SECTION 4. The franchise or charter of said corporation shall not be sold or offered for sale, or leased to any company, or to any person or association of persons, without the consent of the Legislature; and any contract made contrary to the provisions of this act shall be void. And this charter may be revoked by the Legislature for any cause which they deem sufficient.

SECTION 5. The provisions of the first and second sections of the three hundred and tenth chapter of the acts of the year eighteen hundred and sixty-eight shall apply to said telephone company and its licensees. Said corporation shall be subject to all general laws that now are or that may be hereafter in force relating to similar corporations, so far as the same shall not be inconsistent with the provisions of this act.

SECTION 6. This act shall take effect upon its passage.

HOUSE OF REPRESENTATIVES, March 12th, 1880.

Passed to be enacted.

CHARLES J. NOYES, *Speaker.*

IN SENATE, March 17, 1880.

Passed to be enacted.

ROBERT R. BISHOP, *President.*

March 19, 1880. Approved.

JOHN D. LONG.

SECRETARY'S DEPARTMENT, BOSTON, March 19, 1880.

A true copy.

Witness the seal of the Commonwealth.

[SEAL OF THE COMMONWEALTH]

HENRY B. PEIRCE,
Secretary of the Commonwealth.

COMMONWEALTH OF MASSACHUSETTS.

No. 1077.

Be it known that whereas W. H. Forbes, George L. Bradley, G. Z. Silsbee, Charles Eustis Hubbard, Francis Blake, W. G. Saltonstall, Richard S. Fay, R. W. Devonshire, Charles Emerson, Thomas B. Bailey and C. M. Whitcomb have associated themselves with the intention of forming a corporation under the name of the American Bell Telephone Company, for the purpose of manufacturing, owning, selling, using, and licensing others to use, electric speaking telephones, and other apparatus and appliances pertaining to the transmission of intelligence by electricity, and for that purpose constructing and maintaining, by itself and its licensees, public and private lines and district exchanges, with a capital of seven million three hundred and fifty thousand dollars, and have complied with the provisions of the statutes of this Commonwealth in such case made and provided, as appears from the certificate of the President, Treasurer and Directors of said corporation, duly approved by the Commissioner of Corporations, and recorded in this office: —

Now, therefore, I, Henry B. Peirce, Secretary of the Commonwealth of Massachusetts, do hereby certify that said W. H. Forbes, G. L. Bradley, G. Z. Silsbee, C. E. Hubbard, F. Blake, W. G. Saltonstall, R. S. Fay, R. W. Devonshire, C. Emerson, T. B. Bailey and C. M. Whitcomb, their associates and successors, are legally organized and established as and are hereby made an existing corporation under the name of the American Bell Telephone Company, with the powers, rights and privileges, and subject to the limitations, duties and restrictions, which by law appertain thereto.

Witness my official signature hereunto subscribed, and the seal of the Commonwealth of Massachusetts hereunto affixed, this seventeenth day of April, in the year of our Lord one thousand eight hundred and eighty.

(Signed) HENRY B. PEIRCE,

[SEAL] *Secretary of the Commonwealth.*

COMMONWEALTH OF MASSACHUSETTS.
SECRETARY'S DEPARTMENT, BOSTON, Oct. 13, 1880.

I hereby certify that the foregoing is a true copy of the certificate of incorporation of the American Bell Telephone Company, organized under the provisions of chapter two hundred and twenty-four of the Acts of the year eighteen hundred and seventy, and chapter one hundred and seventeen, of eighteen hundred and eighty, having "the force and effect of a special charter," as appears by the records of this department.

Witness the seal of the Commonwealth.

HENRY B. PEIRCE,
[SEAL] *Secretary of the Commonwealth.*

COMPLAINANTS' EXHIBIT HUBBARD'S DECLARATION OF TRUST.

BELL TELEPHONE COMPANY. DECLARATION OF TRUST.

[Liber R[21], p. 400.]

Whereas, Letters Patent of the United States were issued to Alexander Graham Bell as assignor of himself, Thomas Sanders and Gardiner G. Hubbard, bearing date April 6, 1875, and numbered 161,739; to Alexander Graham Bell, bearing date March 7, 1876, and numbered 174,465; to Alexander Graham Bell, bearing date June 6, 1876, and numbered 178,399; and to Alexander Graham Bell, bearing date Jan. 30, 1877, and numbered 186,787.

All of said Letters Patent being for improvements in "Telegraphy, Telephony and Telephonic Apparatus" invented by said Alexander Graham Bell;

And whereas said inventions and said Letters Patent have all been assigned to Gardiner G. Hubbard of Cambridge, in the County of Middlesex and Commonwealth of Massachusetts, Trustee;

And whereas it is proposed to organize an Association for the purpose of manufacturing and introducing said Telephones into general use throughout the United States;

Now, therefore, I, the said Gardiner G. Hubbard, agree to and by these Presents, do place said Patents and all other Patents and Inventions relating to Telephones which I may hereafter receive or acquire; also all the profits and proceeds derived from licensing or authorizing others to make, use, sell and introduce into use, said Telephones, and from the sale of all or any portion or portions or the territorial right to make, use or sell the said Telephones, under said Patents or any of them, after deducting therefrom and paying all the costs, charges and expenses of or incident to said business, in trust. And I will, and my successors in trust shall, hold the same and all the same in trust, until disposed of as hereinafter provided; and I do hereby declare said trust and the terms, conditions, provisions, restrictions and limitations thereof, which shall be and continue equally binding upon me and my successors in trust, and all the persons and parties who now or may hereafter become owners of or interested in the shares herein and hereby created, to wit: —

First. The business of manufacturing Telephones and licensing parties to use the same for a royalty shall be carried on and managed by the trustee under the name of the Bell Telephone Company, under and in accordance with such general directions, rules and regulations as may be made for that purpose by the Board of Managers hereinafter provided for, and all the results and profits thereof, after paying all the proper costs and expenses of carrying on and managing said business, and all the property and money which may be paid to or come into the hands of the said Trustee, belonging to this business, and the proceeds of the sale of said property, if the same shall ever be sold, under the provisions hereinafter contained, shall all be held in trust until the same is paid over to the Association herein and hereby organized; and the rights to the same, when divided, as hereinafter provided for, shall be, and hereby are, divided into five thousand shares.

Second. The owners of said shares shall constitute and become, by the fact of such ownership, an Association of which each individual owner of one or more shares shall be an individual member during such ownership, and in all meetings of such Association herein provided for each and every member of said Association shall be entitled to one vote in person or by proxy, for each and every share

owned by him and standing in his name, and each share shall entitle its owner to its *pro rata* share in all moneys divided by the Board of Managers upon said shares.

Third. No member of said Association shall as such or in consequence of such membership have any right to or control over any property or money in the hands of the Trustee or Treasurer, or of the business herein contemplated, except by and through the Board of Managers herein provided for; and no member of the Association or of the Board of Managers shall have authority or right to bind or render liable the Association, or the individual members thereof, by any contract or obligation whatever.

Fourth. All the business affairs and interests of said Association shall be wholly under the supervision and control of a Board of Managers of not less than three nor more than five persons, of whom the Trustee shall be one, the others to be elected by the members of the Association from their number by ballot; said Board of Managers shall act only as a Board, a majority of them constituting a quorum for business. All the active business of the Association shall be done by agents, clerks and servants, who shall be appointed by and responsible to said Board; and no member of the Association, whether a Manager or not, shall have any authority to act for the association in any way whatever, except as he may be authorized by the Board of Managers. The Board of Managers may refer any question of business of the Association to a meeting of the shareholders, and in such case shall act in accordance with such vote or votes as may be passed in relation thereto; and they shall in all cases when a vote is passed by the shareholders upon any question of interest to the Association be governed by such vote. The Board of Managers shall declare and cause to be paid to the shareholders *pro rata* dividends of net money in the hands of the Treasurer. Meetings of the Board of Managers shall be called in such way as they may prescribe.

Fifth. The Board of Managers and all other officers of the Association shall hold their offices and perform the duties thereof until others are elected or appointed in their places. When a vacancy occurs in the Board of Managers, it shall be filled by an election by

the remaining members of the Board, until the next regular meeting, when the shareholders may elect.

Sixth. A regular annual meeting of the shareholders of the Association shall be held on the first Monday of June in each year, at twelve o'clock, noon, at such place as shall be appointed by the Board of Managers, of which notice shall be addressed by mail to each shareholder at his last known post-office address. At such annual meeting, or any special meeting called in lieu of it, a Board of Managers, Treasurer and Clerk shall be elected, and any other business which may properly come before the Association voted upon. At all meetings of the shareholders, one half in interest in the Association, if no more be present, shall constitute a quorum. The trustee shall preside at all meetings, if present; if not present, a presiding officer shall be chosen. If by mistake or otherwise the annual meeting is not held at the time and in the manner specified, it may be called and held at any time and place designated by the Board of Managers or the Trustee, by sending notice to each shareholder by mail, as above specified, at least ten days before the time designated for the meeting; and the sworn certificate of the Trustee or either one of the Board of Managers, that such notice was given, shall be deemed conclusive evidence that it was so given. A special meeting of the shareholders shall be called by the Trustee or any member of the Board of Managers to vote in relation to any question of interest to the Association, when one third in interest of the shareholders shall make a request in writing to that effect, notice of the meeting and the purpose of it to be given as before provided. A legal meeting of the shareholders may be held at any time when all the shares are represented by the owners in person or by proxy, without any previous notice. Records of all meetings of shareholders and of the Board of Managers shall be made by the Trustee or other person appointed for that purpose by the Board of Managers in books kept by the Association for the purpose, which shall clearly set forth all votes passed or acted upon, which shall be attested by the person making it; and such attestation shall be conclusive of its correctness.

Seventh. Each shareholder in the Association shall be entitled to, and receive from, the Trustee a certificate setting forth how many

shares therein he is the owner of, which certificate shall bear upon the back of it this Declaration of Trust. Shares in this Association and all the rights and interests they represent may be transferred by an assignment in writing on the certificate; but no transfer of shares will be recognized by the Trustee until the old certificate is surrendered and a new one issued, according to the interest of the parties. There shall be kept by the Trustee a record of all the shares of the Association and all transfers of the same, and the residences of the owners as given by them.

Eighth. The Treasurer of the Association, or other officer appointed for that purpose, shall keep a clear and accurate account, by double entry, of all the business transactions of the Association, which said books and all other books of the Association shall always, at reasonable business hours, be open for inspection by the shareowners. The Trustee shall keep a full and complete record of all the business done by him as Trustee under this Trust, which shall at all times be open to inspection by the Board of Managers.

Ninth. If no other provision is made by the Board of Managers, the Trustee shall act as general agent of the Association, and shall perform or cause to be performed under his supervision, and in accordance with the directions of the Board of Managers, the duties of such office until special officers are appointed by the Board of Managers to perform them; and the Trustee or other officer in charge of the business shall pay out of the funds of the Association, subject to the direction of the Board of Managers, all the proper and legitimate charges and expenses incurred by him in and about the management of the business.

Tenth. The property held in trust, or any portion thereof, shall be sold, transferred, conveyed, released and delivered by the Trustee free of and discharged from this trust, or otherwise, whenever he is directed by a vote of the shareholders so to do at a meeting called and held for that purpose, and at which at least seven eighths in interest of the shares are represented; and when such disposition of the trust property is made, and the proceeds thereof, after paying all debts, costs, charges and expenses, have been paid over to the Association, and divided *pro rata* upon all the shares, then this Association shall be dissolved and cease to exist, and, upon payment of

such final dividend, all the certificates shall be surrendered and cancelled.

The decease of any member of the Association shall not work a dissolution of it, nor shall it entitle his legal representatives to an account, or to take any action in the Courts or otherwise against the Association or the Trustee for such account; but they shall simply succeed to the right of the deceased to the certificate and the shares it represents, subject to this Declaration of Trust.

Eleventh. In case of the decease, resignation or inability of the Trustee to act, a special meeting of shareholders shall be called for the purpose, and a new Trustee shall be elected, who shall succeed to all the rights and duties of his predecessor. If the shareholders shall become dissatisfied with the Trustee for any reason whatever, and shall, at a meeting called for that purpose, by a vote of three quarters in interest, request his resignation, he shall cease to be and to act as Trustee, and upon the election of a new Trustee shall convey all the property, rights and interests held by him under this Trust to the new Trustee.

The shares and certificates representing them are issued by the Trustee and accepted by the holder, subject to all the foregoing provisions.

In witness whereof, I, the said Gardiner G. Hubbard, have hereunto set my hand and seal this ninth day of July, 1877.

GARDINER G. HUBBARD. [SEAL]

In presence of

CHAS. EUSTIS HUBBARD.

[Recorded July 28, 1877.]

EXHIBIT NATIONAL BELL TELEPHONE COMPANY ASSIGNMENT. CHAS. H. SWAN, SPECIAL EXAMINER.

Know all men, that the National Bell Telephone Company, a corporation duly created under the laws of Massachusetts, in consideration of one dollar to it paid by the American Bell Telephone ~~Company~~, the receipt whereof is hereby acknowledged, hath granted, to said American Bell Telephone Company sold, assigned and transferred all the right, title and interest, legal

and equitable, which it hath to or under the following described patents of the United States and the inventions therein described, and all reissues and extensions thereof, to wit: —

Number 161,739, dated April 6, 1875, granted to Alexander Graham Bell, Assignor to himself, Thomas Sanders and Gardiner G. Hubbard, for Improvement in Transmitters and Receivers for Electric Telegraphs.

Number 174,465, dated March 7, 1876, granted to Alexander Graham Bell, for an Improvement in Telegraphy.

Number 178,399, dated June 6, 1876, granted to Alexander Graham Bell for improvements in Telephonic Telegraph Receivers.

Number 186,787, dated January 30, 1877, granted to Alexander Graham Bell, for improvements in Electric Telegraphy.

And also, all its right, title and interest in, and to all patents, patent rights, and inventions, whether patented or not, including all licenses and rights to licenses, under inventions heretofore made and hereafter to be made.

To have and to hold the rights and interests hereby assigned to the said American Bell Telephone Company, its successors and assigns, to their own use and behoof forever.

In witness whereof the said National Bell Telephone Company hath caused its corporate seal to be hereto affixed, and these presents to be subscribed by its president and treasurer, thereto duly authorized this eighth day of May A. D. 1880.

THE NATIONAL BELL TELEPONE COMPANY.

[Seal of Nat'l Bell Tel. Co.]

By William H. Forbes, *Prest.*
Wm. R. Driver, *Treas.*

In presence of (the words, "to said American Bell Telephone Company" being interlined before the execution hereof) W. P. Montague.

UNITED STATES PATENT OFFICE.

HENRY CLAY, OF PHILADELPHIA, PENNSYLVANIA, ASSIGNOR TO THE CLAY COMMERCIAL TELEPHONE COMPANY, OF SAME PLACE.

TELEPHONIC TRANSMITTER.

SPECIFICATION forming part of Letters Patent No. 298,286, dated May 6, 1884.

Application filed May 1, 1883. (No model.)

To all whom it may concern:

Be it known that I, HENRY CLAY, a citizen of the United States, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Improvements in Telephonic Transmitters, of which the following is a specification, reference being had therein to the accompanying drawings, whereiu—

Figure 1 is a vertical section of an electric transmitter embodying my invention. Figs. 2 and 3 are respectively a perspective and an elevation of details. Fig. 4 is a vertical section illustrating modified arrangement of circuits. Fig. 5 is a similar view of a modification of my invention, and Figs. 6 and 7 are respectively a perspective and a section of further modifications.

My invention has relation to that class of telephonic transmitters wherein the changes of pressure upon a carbon block cause it to offer different resistances to the passage of an electric current, so as to vary its strength in unison with the rise and fall of vocal utterances; and it has for its object to simplify the construction of the instrument, make it more compact and durable, regulate the force of contact of the electrodes, and increase the electro-motive force of the induced currents.

My invention accordingly consists of the novel combination, construction, and arrangement of parts, as hereinafter described and claimed.

In the drawings, A represents a box or casing having a hinged lid, *a*, to which is suitably secured a diaphragm, B, having a platina or other electrode, *b*, attached thereto. On each side of said electrode, and secured to diaphragm B, are brackets or supports C, which have an upward inclination, as shown, so that when the carbon block D is placed thereon it automatically maintains its contact with the electrode *b*.

b' represents another electrode secured to a bar, *e*, fastened to the ends *e' e'* of an induction-coil, E, the core e^2 of which is pivoted at *f* to a nut, F, engaging with a screw, G, having a shoulder, *g*, and bearings g' g^2 in an arm or bracket, H, secured to door *a* or one of the sides of the box A. The core e^2 is cut away at e^3 or at its lower end, which is in line with a soft-iron or other bar, I, capable of being magnetized. Said bar is threaded at *i*, and is supported by the door *a*, so as to be adjustable to and from the end e^3 of core e^2. By turning the screw G the nut F is adjusted thereon, to regulate the contact of electrode *b'* with carbon block D, and such initial contact is duly maintained by the gravity of the induction-coil E, while the pivotal connection of the latter permits it to yield to the vibrations of the diaphragm B.

J represents the local battery or generator in circuit with the electrodes and the primary circuit of the induction-coil E, and 1 the line leading to the secondary circuit of such coil, and is suitably grounded, as shown at 2. Such arrangement is the usual one, and is more plainly shown in Fig. 4.

The operation is as follows: The initial adjustment of the screw G being made for obtaining corresponding contact of the electrodes, the bar I is adjusted until its end *i'* nearly but not quite contacts with the end e^3 of core e^2. The sound-waves vibrating the diaphragm B vary the strength of the battery-current and set up corresponding induced currents in the secondary circuit of the coil E in the customary manner, and correspondingly magnetize the core e^2, which in turn is proportionately attracted by bar I, and thereby regulates the force of contact of the electrodes in unison with the vibrations of the diaphragm, to obtain a more efficient variation in the battery-current; or, in other words, the coil E is not only an induction coil, but also acts as a governor for regulating the force of contact of the electrodes and a damper for the diaphragm, which is prevented from having prolonged vibrations by the gravity of the induction-coil. The variations of the magnetic charge induced in core e^2 variably magnetize bar I for regulating the force of contact of the electrodes.

It will be noticed that the carbon block D is loose upon the supports C, and presents diametrical points for contact with the electrodes, as more plainly shown in Figs. 2 and 3. Consequently, as the diaphragm vibrates, the block D rotates and presents new points of contact for the electrodes. This revolving of the block D is caused by vibratio[illegible]as of the diaphragm, which at each vibration leaves a small space for the block to roll in. While

the partial revolution of the block at each vibration of the diaphragm is very minute, in the aggregate it is sufficient to turn the block in such a manner as to make the wear upon the latter uniform.

If an aural tube, K, is attached to box A as represented in Fig. 1, the instrument may be used as a receiver, as well as a transmitter, the receiving sound-waves being produced by the vibration of the diaphragm.

In Fig. 5 I have represented my invention applied to a portable or hand transmitter, wherein the screw G and appurtenances are dispensed with, a spring being substituted therefor, the carbon block D resting within a recess on the bar *e*, and the core e^2 is provided with an adjusting-screw, M, having an insulated end, *m*. The casing A has an aural or ear piece, as shown.

In Fig. 6 is shown a deflector, L, which serves the same purpose as the tube K. In this figure the diaphragm B is in the front of the device, and the deflector L is at one end, and so shaped as to be opposite the ear. The sound from the diaphragm passes through the opening L′ in the case to the deflector, and from thence out of opening L^2.

In Fig. 7 I have illustrated a modified arrangement of the primary and secondary circuits of the induction-coil E. Such construction causes the received articulations to be more distinct or pronounced by reason of a part of the secondary circuit being wound next the core e^2. While I have shown the supports C having inclined sides, in order that the gravity of the block D may be utilized to maintain its contact with the electrode *b*, yet I do not confine my invention thereto, as said supports may be right-angle brackets and the box A tilted forward at its upper end to cause said block to make contact with electrode *b*. So, too, while I have represented screw and spring mechanism for causing the core e^2 and coil E to maintain contact of electrode *b′* and block D, yet I do not limit myself thereto, as any other suitable mechanism or appurtenances that will accomplish such result may be substituted therefor, said coil being in all cases provided with or carrying the electrode *b′*.

I am aware that a swinging bar, a diaphragm, electrodes interposed between the bar and diaphragm, and an electro-magneto-controlling device combined together are old. My device differs from that form in that I dispense with the bar and electro-magnetic-controlling device, and substitute an induction-coil which has electrodes interposed between it and the diaphragm.

I am aware that a carbon block has been held between two brackets, each attached to a separate diaphragm, and to that I make no claim. My device differs from this construction in that both brackets are attached to one part, as shown.

electrodes interposed between said diaphragm and induction-coil, which by its gravity maintains and regulates the force of contact of said electrodes, substantially as described.

2. In a telephonic transmitter, the combination of a diaphragm, an adjustably suspended or supported induction-coil, and electrodes interposed between the diaphragm and induction-coil, substantially as described.

3. The combination, with a diaphragm, B, having brackets C C, and electrode *b*, of a carbon block, D, held on said brackets, and electrode *b′*, substantially as described.

4. The combination of a diaphragm carrying an electrode, a suspended and adjustable induction-coil having an electrode, and a carbon block between said electrodes, substantially as shown and described.

5. The combination of a diaphragm, B, induction-coil E, having a projecting core, electrodes interposed between the diaphragm and coil, and magnetic bar I, substantially as described.

6. In a telephonic transmitter, the combination of a diaphragm and an induction-coil arranged to regulate by its gravity the force of contact between the electrodes and to dampen the prolonged vibrations of said diaphragm, substantially as set forth.

7. The combination of diaphragm B, induction-coil E, having core e^2, electrodes interposed between the diaphragm and coil, and magnetic bar I, substantially as shown and described.

8. The combination of diaphragm B, induction-coil E, having core e^2, electrodes interposed between the diaphragm and coil, bar I, and ear piece or tube K, substantially as shown and described.

9. The combination of diaphragm B, the pivoted or suspended induction-coil E, having core e^2, electrodes interposed between the diaphragm and coil, and adjustable bar I, substantially as shown and described.

10. The combination of diaphragm B, pivoted and adjustable induction-coil E, electrodes interposed between the diaphragm and coil, and adjustable bar I, substantially as shown and described.

11. In a telephonic transmitter, the combination, with the induction-coil E, of core e^2, nut F, and screw G, substantially as shown and described.

12. The combination of diaphragm B, carrying electrode *b*, and brackets C C, the adjustable induction coil E, carrying electrode *b′*, and the carbon block D, supported upon said brackets, and presenting diametrical points of contact to the electrodes, substantially as shown and described.

In testimony whereof I affix my signature in presence of two witnesses.

HENRY CLAY.

sides of the box A. The core e^2 is cut away at e^3 or at its lower end, which is in line with a soft-iron or other bar, I, capable of being

of the block D is caused by vibrations of the diaphragm, which at each vibration leaves a small space for the block to roll in. While

(No Model.) 2 Sheets—Sheet 1.

H. CLAY.

TELEPHONIC TRANSMITTER.

No. 298,286. Patented May 6, 1884.

Fig. 1.

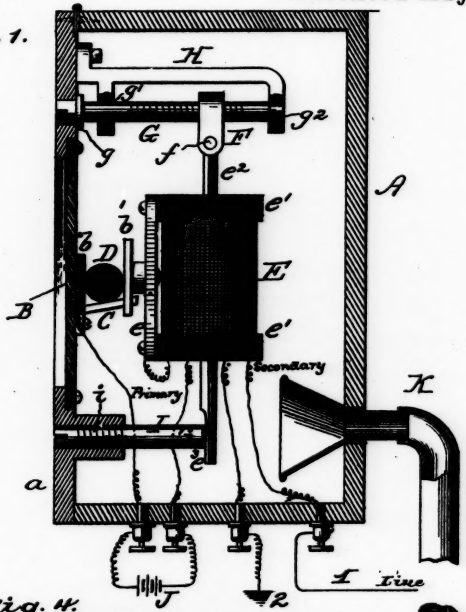


Fig. 4.

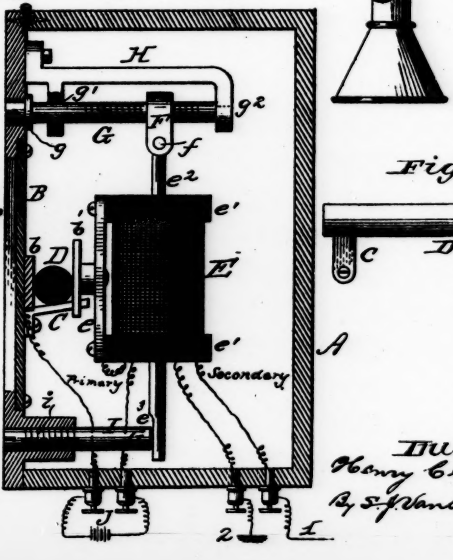


Fig. 2.

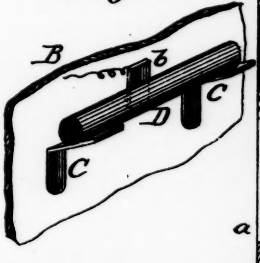
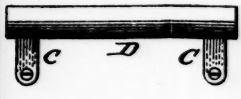


Fig. 3.



Attest:
A. M. Long
C. W. Williams

Inventor
Henry Clay
By S. P. Vanbrevoort
Atty.

(No Model.) 2 Sheets—Sheet 2.

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H. CLAY.

TELEPHONIC TRANSMITTER.

No. 298,286. Patented May 6, 1884.

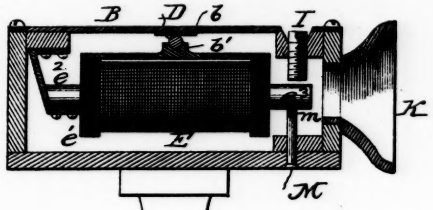


Fig. 5.

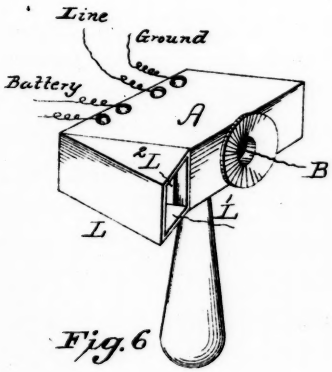


Fig. 6

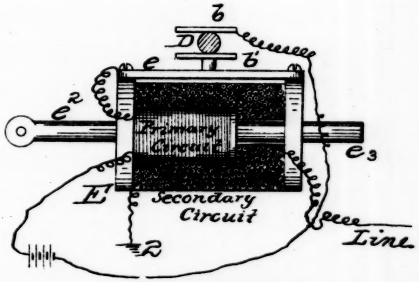
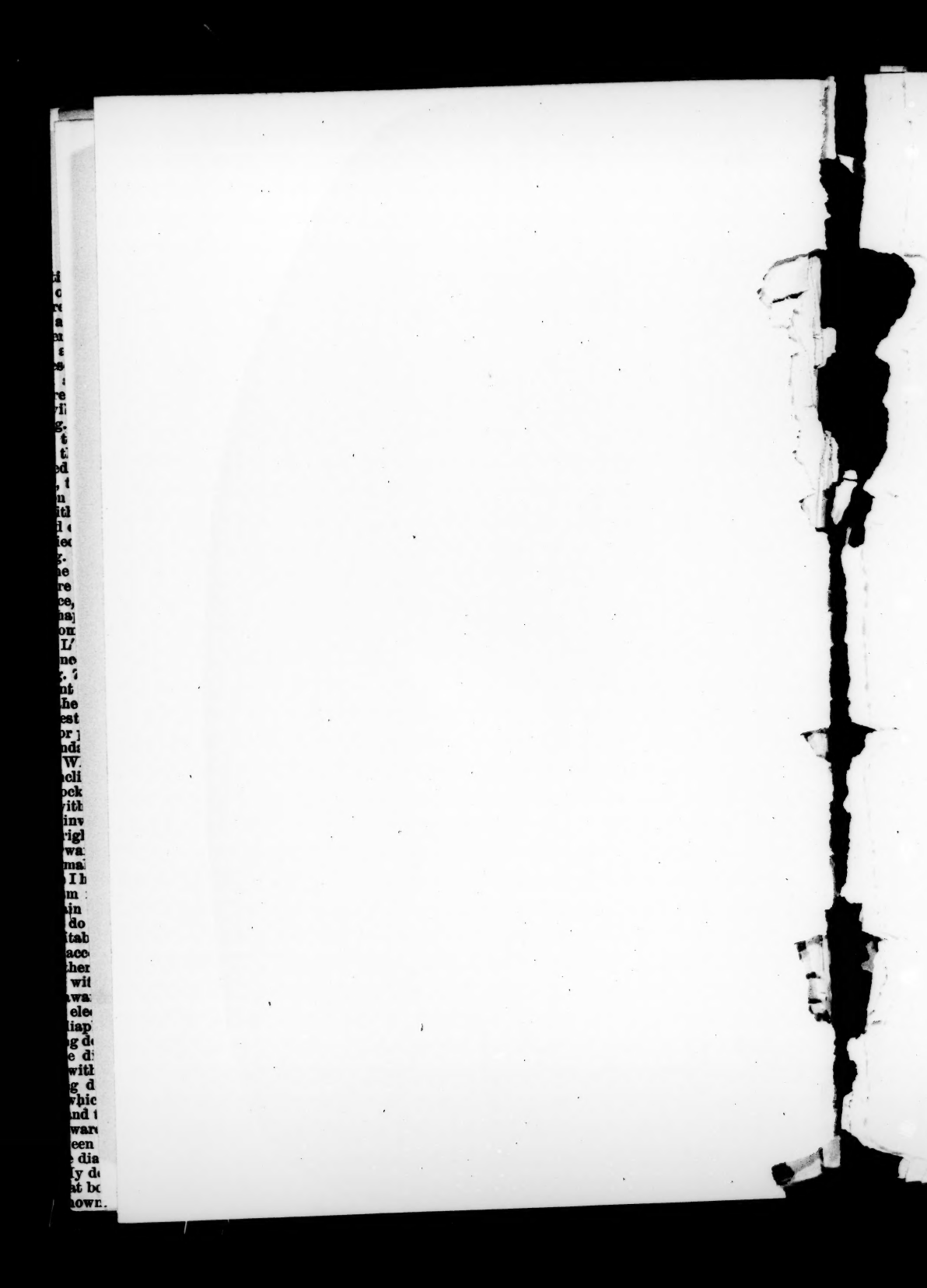


Fig. 7

Attest:
A. M. Long.
C. W. Williams

Inventor.
Henry Clay
By J. P. Van Santvoord
Atty.



UNITED STATES PATENT OFFICE.

HENRY CLAY, OF PHILADELPHIA, PENNSYLVANIA.

TELEPHONE.

SPECIFICATION forming part of Letters Patent No. 277,112, dated May 8, 1883.

Application filed September 21, 1882. (No model.)

To all whom it may concern:

Be it known that I, HENRY CLAY, a citizen of the United States, residing in the city and county of Philadelphia, State of Pennsylvania, have invented a new and useful Improvement in Telephones, which improvement is fully set forth in the following specification and accompanying drawings, in which—

Figure 1 is a front view of the telephone embodying my invention. Fig. 2 is a side elevation thereof. Fig. 3 is a section thereof in line *x x*, Fig. 2. Fig. 4 is a section thereof in line *y y*, Fig. 3.

Similar letters of reference indicate corresponding parts in the several figures.

My invention consists of certain improvements in telephones, the construction, operation, and advantages whereof will be hereinafter fully set forth.

Referring to the drawings, A represents a compound or complex magnet formed of the poles or limbs *a a b*, connected as at *a'*, the poles *a a* being north, and the pole *b* south, or vice versa.

B represents the cap of the mouth or ear piece C; and D represents a spool, which is secured within said cap B, at the back thereof and has the legs of the magnet A passed through it, so that their ends project beyond the inside thereof.

To the ends of the poles or limbs *a a* is secured an annulus, E, with which is magnetically connected a diaphragm, F, it being noticed that the pole *b* occupies a position adjacent to the inner face of the center of the diaphragm, but is not in contact therewith, as more readily seen in Fig. 3.

G represents a coil of wire which is within the spool D, said wire inclosing the entire magnetic field—that is to say, the poles *a a* and *b* collectively, but not surrounding any one of said poles individually. This wire coil forms part of an electric circuit, being connected to binding-posts and screws G' G', and is the magnetizing-helix of the magnet. Of course a permanent magnet may be employed instead of a temporary one.

The instrument is shown as a receiver, and the action of the current coming from the connected instrument over the wires which enter or are secured to the posts G' is continued through the coil G around the entire magnetic field, and as the current varies, the magnet- erts its action on the diaphragm F, causing the same to vibrate, and thus to emit sounds corresponding to those received by the instrument at the other end of the line.

It will be seen that as the diaphragm is firmly connected with the poles *a* of the compound magnet through the annulus E, and said diaphragm is free to move opposite the pole *b*, its vibrations become more violent and the transmitted sound more audible.

By the use of the magnet and passage of the wire of the coil G in planes at a right angle to the axis of the pole *b* and partly around the two poles *a*, I obtain an instrument which will convey and deliver the sound with but slight loss of its intensity.

The diaphragm acting as a keeper, being in close proximity to the south pole and magnetically connected with the north pole, augments and strengthens the magnetic curves, and causes the instrument to continually become more effective in action instead of diminishing.

When the instrument is to be used as a transmitter the construction is not varied; but the action is in reversed order to that stated.

Having thus described my invention, what I claim as new, and desire to secure by Letters Patent, is—

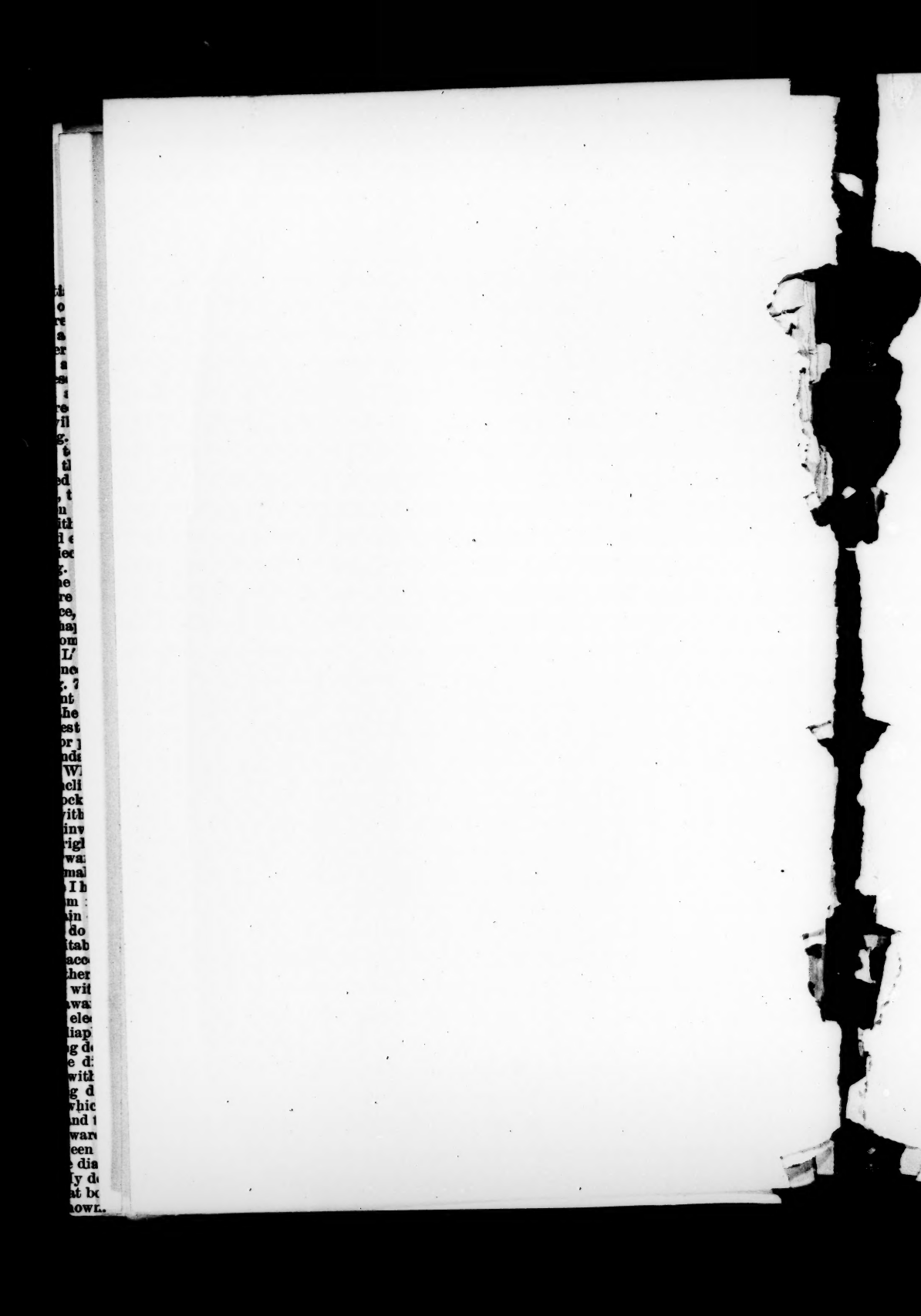
1. In a telephone, a magnet having three poles, *a a b*, the former two being of opposite polarity to the latter, in combination with a helix or coil of wire surrounding all the poles collectively, and a diaphragm attached to the poles *a a*, but not attached to the pole *b*, substantially as set forth.

2. A compound magnet consisting of three limbs, the middle one being of polarity opposite to that of the others, in combination with a metallic plate or armature which is attached to the two outer poles, but not to the middle pole, as set forth.

3. A magnet consisting of three connected limbs, the middle being of polarity opposite to that of the outer limbs, in combination with a metallic plate or armature attached to the two outer limbs, but free from the middle limb, and a helix which surrounds all the poles collectively, but no one of them individually, substantially as set forth.

HENRY CLAY.

Witnesses:
JOHN A. WIEDERSHEIM,
A. P. GRANT.



(No Model.)

H. CLAY.

TELEPHONE.

No. 277,112. Patented May 8, 1883.

Fig. 1.

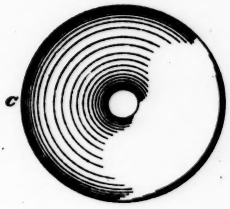


Fig. 2.

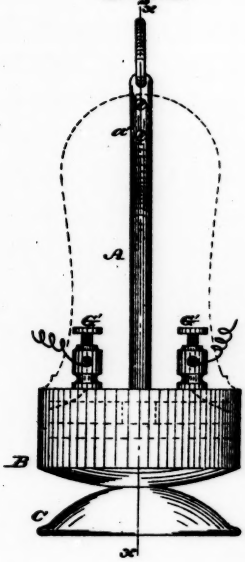


Fig. 3.

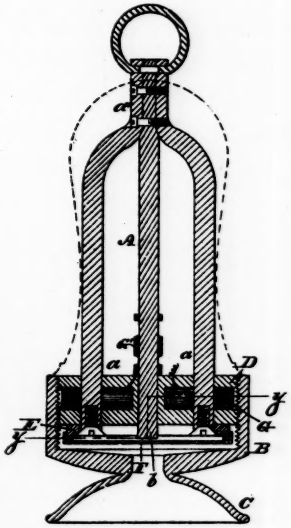
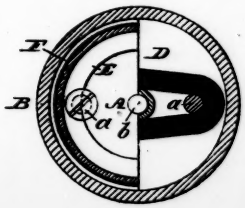


Fig. 4.



WITNESSES:

A. D. Grant,

W. E. Leicher

INVENTOR:

Henry Clay,

BY John A. Diedesheim

ATTORNEY.

instrument is

DEPOSITION OF CHARLES EUSTIS HUBBARD.

BOSTON, November 21, 1884.

Direct Examination by GEORGE L. ROBERTS, Esq., *of Counsel for Complainants.*

Int. 1. State your name, age, residence, and occupation.

Ans. Charles Eustis Hubbard; I am forty-two years old; I live in Boston, and am a lawyer.

Int. 2. I show you a certified copy of certain assignments marked "Exhibit Assignments," and call your attention to the first instrument contained therein, dated July, 1877, which shows the name of Charles Eustis Hubbard as an attesting witness. Please state whether you remember to have witnessed the execution of the original assignment, and to have signed the same as the attesting witness thereof.

[Mr. SHEPPARD *objects to the question.*]

Ans. I do. I drafted the original of which this is a copy, and it was executed by Mr. Bell in my office and witnessed by me.

Int. 3. The grantee of this instrument is Gardiner G. Hubbard, trustee; was there, to your knowledge, a written instrument defining the powers and duties of such trustee, and what relation is the said Gardiner G. Hubbard to you?

Ans. There was such an instrument defining the trust. It was drafted by me. Said Gardiner G. Hubbard is my brother.

Int. 4. Please examine the certified copy now shown you, and state whether it is a copy of the declaration of trust just referred to by you, and whether you remember to have witnessed the execution of it.

Ans. I have examined the certified copy shown me, and have no doubt it is a correct copy of the original declaration of trust which was executed in my office and witnessed by me.

[*Counsel for complainants puts the said certified copy in evidence, and the same is marked "Exhibit Hubbard's Declaration of Trust, Chas. H. Swan, Special Examiner."* Mr. SHEPPARD, *for defendants, objects to the offer of evidence, for the reasons, among others, that said trust is inoperative and invalid in law; that said instrument is*

not a recordable instrument; that a copy certified by the Patent Office is not legal evidence; and that the execution of the original paper, of which the paper offered purports to be a copy, is not duly proven.]

Int. 5. You say, in answer to Int. 4, that this declaration of trust was executed in your office. To save any informality of testimony, please state by whom it was executed, and whose signature you witnessed.

Ans. It was executed by Gardiner G. Hubbard; signed "Gardiner G. Hubbard, Trustee"; and I witnessed his signature.

Int. 6. This declaration of trust provides for management on behalf of the beneficiaries by a Board of Managers and by action of the beneficiaries as an Association; did you hold any official position in this Association; and if so, what?

Ans. I did. I was the clerk of the Association, and one of the Board of Managers.

Int. 7. Did you ever have in your possession as clerk of the said Association the original assignment of July, 1877, from Alexander Graham Bell to Gardiner G. Hubbard, trustee, a certified copy of which you have identified: and the original declaration of trust signed by Gardiner G. Hubbard, a certified copy of which you have also identified; and if you ever had such original papers in your possession, state whether you know where they now are, and with what diligence you have made search for them.

Ans. I did have them in my possession as counsel for the parties in interest, and forwarded them to the Patent Office for record. This was before the organization of the Association. To the best of my recollection, they were returned to me from Washington and were in my custody as clerk of the Association; but though I have made diligent search for them in various places, I have been unable to find them, and do not know where they are.

Int. 8. I show you a paper which purports to be an assignment from Gardiner G. Hubbard, trustee, to the Bell Telephone Company, dated July 20, 1878, and recorded in the Patent Office, Oct. 3, 1878, Liber Y[22], page 460, of Transfers of Patents. Please state whether your signature is upon this instrument as one of the attesting witnesses,

and what you know as to its execution, and the genuineness of the signature of Gardiner G. Hubbard, trustee, which appears thereon.

Ans. My signature is upon that instrument. The assignment was drafted by me, is in my own handwriting, and was executed by Gardiner G. Hubbard, as trustee, in my presence.

Int. 9. Will you please refer to the book of records kept by you as clerk of the Association for whose benefit this trust was held, and state whether any authorization was made for the assignment which you have just identified, dated July 20, 1878; and if so, what records were made of it?

Ans. There was; I have examined the book of records of the said Association, which were kept by me as clerk in my own handwriting, and find the following record relating to the subject inquired of: —

"SHAREHOLDERS' MEETING.

"In accordance with the following notice sent to each of the shareholders at least ten days before the time fixed for the meeting.

"BOSTON, July 8, 1878.

"*To*.....

Shareholder of the Bell Telephone Company: —

"You are hereby notified that the annual meeting of the Bell Telephone Company will be held at No. 13 Sears Building, Boston, on the eighteenth day of July, 1878 (Thursday), at 12 M. to consider, in addition to the regular business of the meeting, whether the Association will ratify the contract of the Trustee with the Telephone Company of New York, and whether the Association will authorize the Trustee to sell and dispose of all the property held in trust for the Association, and upon what terms and conditions.

"Per order of the Trustee,

"C. E. HUBBARD.

"*Clerk of the Bell Telephone Company.*"

The annual meeting of the Association was held at No. 13 Sears Building, Boston, on Thursday, July 18th, 1878, at 12 M. Owing to the absence of the trustee, on motion of Thomas Sanders, it was

Voted, To adjourn to meet at the same place on Friday, July 19th, 1878, at eleven o'clock A. M.

Attest: C. E. HUBBARD, *Clerk.*

The shareholders of the Bell Telephone Company met by adjournment at No. 13 Sears Building, Boston, on Friday, July 19th, 1878.

Present in person or by proxy, Gardiner G. Hubbard, Thomas Sanders, Mabel G. Bell, Thomas A. Watson, Gertrude McC. Hubbard, and C. E. Hubbard, representing 4,490 out of 5,000 shares.

. . . . . .

The following preamble having been offered by Thomas Sanders:

Whereas, it is proposed to organize a corporation under the laws of the Commonwealth of Massachusetts, to be known as the Bell Telephone Co., to manufacture, and sell telephones and their appurtenances, and to construct, maintain and operate telephone lines, and rent telephones throughout the United States outside of the New England States, with a capital stock of $450,000, the number of shares to be forty-five hundred, the par value of the shares to be $100, and

Whereas, the parties organizing said corporation desire to purchase and acquire all the patent rights, contracts, instruments, leases, books and personal property of every kind and description belonging to, and held in trust by the Trustee of the Bell Telephone Association for said Association, save and except one thousand shares of stock in the New England Telephone Company, belonging to said Association, and held in trust by Gardiner G. Hubbard, Thomas Sanders, and Thomas A Watson.

It was unanimously

Voted, That the Trustee be and he hereby is, authorized, instructed and empowered to sell, assign and transfer by proper and sufficient conveyance, to said Bell Telephone Company, all the patents, patent rights and interest in any and all contracts relating to any patents or future inventions owned or held by him as Trustee, said company assuming all such contracts and the burdens and obligations of said Trustee, thereunder, paying for such assignment, three thousand shares of its capital stock fully paid up.

. . . . . .

Attest:

C. E. HUBBARD,
Clerk.

Int. 10. It appears by this record that of the shareholders of the association there were present in person, or by proxy, at the adjourned meeting of July 19, 1878, Gardiner G. Hubbard, Thomas

Sanders, Mabel G. Bell, Thomas A. Watson, Gertrude McC. Hubbard, and C. E. Hubbard. How many shareholders in all were there belonging to this association, and who was absent from this meeting?

Ans. There were but seven shareholders belonging to the Association during the whole period of its existence. Alexander Graham Bell was the only shareholder not represented at this meeting.

Int. 11. I now show you a written instrument purporting to be an assignment from the Bell Telephone Company to the American Bell Telephone Company, dated June 22, 1880, and recorded in the Patent Office, June 24, 1880, Liber I^{25}, page 282 of Transfers of Patents. Please state whether you know the signatures which appear thereon, and how you have derived your knowledge of the handwriting.

[Mr. SHEPPARD, *for defendants, objects to the question, for the reason among others, that it calls for irregular and inadmissible proof of the execution of an assignment by a corporation*]

Ans. I do know the signatures thereon. They are those of W. H. Forbes and William R. Driver. The former signs as president of the Bell Telephone Company, the latter as treasurer. I am familiar with the handwriting of both signers, having frequently seen them write; and having constant occasion to see their signatures from my position as clerk of the American Bell Telephone Company and of the Bell Telephone Company, of which they are respectively the president and treasurer.

Int. 12. Will you refer to the records of the Bell Telephone Company kept by you, and state when in the year 1880 the said W. H. Forbes was re-elected president, and the said William R. Driver, treasurer?

Ans. On the twenty-first day of June, 1880, at a special meeting of the stockholders of the Bell Telephone Company, duly called, at which a quorum was present, William R. Driver was duly elected treasurer of the company, and William H. Forbes was duly elected a director of said Bell Telephone Company. At a meeting of the directors of the Bell Telephone Company, duly called, and held June 22, 1880, William H. Forbes was duly elected president of the Bell Telephone Company. I was clerk of the company, and I obtain

this information from the records of the company, which were kept by me, and which are in my handwriting.

Int. 13. What authorization by the Bell Telephone Company was there for the execution of this assignment on its behalf by its president and treasurer to the American Bell Telephone Company?

Ans. At a meeting of the stockholders of the Bell Telephone Company, duly called and held at the company's office, June 21, 1880, at which meeting a quorum was present, a vote was passed authorizing the president and treasurer to make the assignment and transfer referred to in the interrogatory. A copy of the vote giving such authority, duly certified by me as clerk of the Bell Telephone Company, is annexed to said instrument of transfer.

Int. 14. Referring once more to the records of the association established under the declaration of trust executed by Gardiner G. Hubbard, trustee, it appears that the notice of July 8, 1878, is addressed to "Shareholder of the Bell Telephone Company." Will you explain the distinction between this name, Bell Telephone Company, as applied to the said association, and the same name which appears in the two assignments you have identified of Gardiner G. Hubbard, trustee, to the Bell Telephone Company, dated July 20, 1878, and of the Bell Telephone Company to the American Bell Telephone Company, dated June 22, 1880?

Ans. The name Bell Telephone Company used in said notice of July 8, 1878, was merely a name given to an association or partnership interested in the property, the legal title to which was in the name of Gardiner G. Hubbard, trustee. The Bell Telephone Company, to whom the said Gardiner G. Hubbard, trustee, made the assignment dated July 20, 1878, and which made the assignment to the American Bell Telephone Company, dated June 22, 1880, is a legal corporation, duly incorporated under the laws of Massachusetts.

[*Counsel for complainants offers in evidence the two assignments identified by the witness, namely, that from Gardiner G. Hubbard, trustee, to the Bell Telephone Company, dated July* 20, 1878, *and that from the Bell Telephone Company, to the American Bell Telephone Company, dated June* 22, 1880.

Mr. SHEPPARD, [illegible] objects to said offer.

It is agreed by counsel for the respective parties, that the certified copies of these two assignments already put in evidence, may be used with the same force and effect as the originals; but that the originals shall be produced at any time for use of defendants, on call of their counsel, if they so desire]

Cross Examination by FURMAN SHEPPARD, Esq., *of Counsel for Defendants.*

Cross-Int. 15. Please state when the assignment of 1877, mentioned by you in your answer to Int. 2 was, executed.

Ans. It was executed July 9, 1877.

Cross-Int. 16. When did you last see the original of said assignment?

Ans. It is impossible for me to say.

Cross-Int. 17. Will you be kind enough to give me the nearest indication of date which your recollection enables you to do?

Ans. I can only say that I remember seeing it on its return from Washington, where I sent it to be recorded in the Patent Office, and the reason of my recollection is this: This assignment and the declaration of trust of Gardiner G. Hubbard were executed at one and the same time, and on the return of these two instruments I discovered that the day of the month had been omitted in the assignment, and I have a distinct recollection of considering whether I should have the date inserted and the paper returned to Washington to be again recorded. I have no special recollection of seeing the paper since that time, but have no doubt I did. I have twice changed my office since the execution of that paper, and probably lost the paper during one of those removals.

Cross-Int. 18. When and where did you last make search for this assignment, and for the declaration of trust, of which you have spoken?

Ans. I made a long and careful search in December, 1883, for these papers in two safes, or vaults, in my present office, 28 State Street; also in the vault in the office of Mr. Gaston, with whom I occupied the office in Sears Building, where I kept these papers after they were returned from Washington, as I have stated, in the possibility that they might have got among his papers. I also

made search among several boxes of papers at the house of my brother, Gardiner G. Hubbard, said boxes containing papers belonging both to my brother and Alexander Graham Bell, his son-in-law.

Cross-Int. 19. You have stated that you have no doubt that the certified copy of the declaration of trust is a correct copy of the original; and also that you have not seen the original for perhaps seven years. Please state how it is that you are free from doubt under such circumstances.

Ans. The original declaration of trust was sent by me to Washington to be recorded in the Patent Office, and was returned to me with the usual certificate of record. The paper now shown me purports to be a certified copy of that record, and I have compared it with a copy of the declaration of trust, which is in the book of records of the said Bell Telephone Association, which last-mentioned copy was printed under my supervision from the original, and was placed in the said book of records by me at the organization of the said Association. I have, therefore, no doubt that the paper in question is a correct copy of the original.

Cross-Int. 20. Your freedom from doubt, therefore, arises from the credit which you give to the Patent Office exemplification or copy of the original, and from the fact that you have compared the Patent Office copy with another copy of the original, and have found the two copies to correspond?

Ans. It does.

Cross-Int. 21. Of the seven shareholders or members named by you of the Association called the Bell Telephone Company, please state how many and which of them were then or are now in anywise related to each other; and if so, how.

Ans. Gardiner G. Hubbard is the father of Gertrude McC. Hubbard and Mabel G. Bell, and the brother of C. E. Hubbard, myself. Alexander Graham Bell is the husband of Mabel G. Bell. Thomas Sanders and Thomas A. Watson are in no way related to each other or the other shareholders.

Cross-Int. 22. Mr. Watson had been assisting or co-operating with Mr. Alexander Graham Bell in his experiments and investigations, had he not?

Ans. He had been employed by Mr. Bell

Cross-Int. 23. What relation had Mr. Sanders with Mr. Bell?

Ans. Mr. Sanders and Gardiner G. Hubbard furnished the means to enable Mr. Bell to pursue his experiments and work in telephonic and telegraphic invention.

Cross-Int. 24. What was Mr. Bell's interest in the Association?

Ans. Mr. Bell, Mr. Hubbard, and Mr. Sanders owned the inventions and patents in equal third parts. The majority of Mr. Bell's interest in the Association was, in accordance with a previous arrangement, given to his wife, Mabel G. Bell.

Cross-Int. 25. Were these one-third interests held by the three persons whom you have named, severally or jointly?

Ans. They were held jointly, until they took the form of shares in this Association. Then they were divided according to the respective interests. This was August 1, 1877.

Cross-Int. 26. Please give me the allotment of shares made at that time.

Ans.	Mabel G. Bell,	1,497
	Alexander Graham Bell,	10
	Thomas A. Watson,	499
	Thomas Sanders,	1,497
	Gertrude McC. Hubbard,	100
	Gardiner G. Hubbard,	1,387
	Charles Eustis Hubbard,	10
	Total,	5,000

I desire here to state that there is a clerical error in the record of the shareholders' meeting of the said Association, held July 19, 1878. The record states that there was represented at that meeting 4,490, out of 5,000 shares. It should have been 4,990, instead of 4,490; Mr. Bell's ten shares being the only ones not represented at that meeting.

Cross-Int. 27. You have mentioned that Mr. Sanders and Mr. Gardiner G. Hubbard furnished the means to enable Mr. Bell to pursue his experiments. Please state what was Mr. Bell's pecuniary condition in 1874, 1875, 1876, and 1877.

[*Objected to as immaterial and inadmissible, not being a subject opened in the direct examination.*]

Ans. I do not know.

Cross-Int. 28. Is that the whole of the information you are able to give on that subject?

[*Same objection.*]

Ans. If I remember rightly, I became acquainted with Mr. Bell some time in 1875. At that time he was connected with the Boston University as an instructor, and also had, I believe, some private pupils. I saw but little of him until the spring of 1876. Of my own knowledge I do not know what his income was during any of the years in question. In 1877 he had some property, certainly, after his marriage; but I was not conversant with his financial matters.

Cross-Int. 29. When did you first become aware that the assignment and declaration of trust, of which we have spoken, were missing?

Ans. In December, 1883.

Cross-Int. 30. What was the National Bell Telephone Company, which is named in the assignment offered in evidence from the Bell Telephone Company to the American Bell Telephone Company, dated June 22, 1880, and how, and when was it constituted?

Ans. The Association of which Gardiner G. Hubbard was the trustee was the first owner of the Bell telephone patents. The New England Telephone Company was next organized as a corporation to carry on the telephone business in New England, under license from Gardiner G. Hubbard, trustee. The Bell Telephone Company was next incorporated in July, 1878, to carry on business for the whole of the United States outside of New England. The National Bell Telephone Company was next organized, March 10, 1879, and the certificate of incorporation issued thereafter, and the Bell Telephone Company and the New England Telephone Company were merged in the National Bell Telephone Company, but the corporate existence of the Bell Telephone Company and New England Telephone Company has never ceased. The American Bell Telephone Company was incorporated by special charter, and is the successor of the National Bell Telephone Company, the date of the charter being March 19, 1880.

[*Defendants' counsel calls for the production of the agreement between the Bell Tel*

Company, dated March 20, 1879, *and also the agreement between the National Bell Telephone Company and the American Bell Telephone Company, dated May* 8, 1880, *each of which is mentioned in the assignment of the Bell Telephone Company to the American Bell Telephone Company, offered in evidence and dated June* 22, 1880.

Counsel for complainants states that, as it appears from the instrument of assignment referred to of June 22, 1880, *that the agreements therein mentioned of March* 20, 1879, *and May* 8, 1880, *are merely collateral, and do not affect the legal title to the patents in suit, he declines to produce them, as at present advised; but counsel for complainants puts in evidence an assignment from the National Bell Telephone Company to the American Bell Telephone Company, dated May* 8, 1880, *and recorded in the United States Patent Office, July* 22, 1880, *Liber R*[25], *page* 105, *of Transfers of Patents.*

Defendants' counsel objects to said offer of evidence for the reason, among others, that it is a source of title in the complainants not set forth in the bill of complaint and inconsistent with the title therein set forth; that the execution of said paper is not duly proven; that the alterations upon its face are not duly accounted for, and that it is irrelevant.

It is agreed by counsel for the respective parties that the examiner may make a fac-simile *copy of this instrument last put in evidence, and that the same may be used with the same force and effect as the original, and introduced into the record as Exhibit National Bell Telephone Company Assignment, Chas. H. Swan, Special Examiner, and that the original shall be produced hereafter, upon call of defendants' counsel, for reference or for comparison with the copy if need be.*]

Direct Examination resumed.

Int. 31. Were you the clerk of the National Bell Telephone Company in 1880, and have you the records of that corporation kept by you here present?

Ans. I was; and am the only clerk the company has ever had. I have the records.

Int. 32. Did that company take any action authorizing the Bell Telephone Company to assign to the American Bell Telephone Com-

pany the patents, No. 174,465, and No. 186,787, originally granted to Alexander Graham Bell; and if so, when and what was it?

Ans. It did. At a special meeting of the stockholders of the National Bell Telephone Company, duly called and held at the company's office, June 21, 1880, at which meeting a quorum was present, it was —

"*Voted*, That the president be, and he hereby is, instructed to request the Bell Telephone Company to assign to the American Bell Telephone Company the patents, No. 174,465, dated March 7, 1876, and No. 186,787, dated Jan. 30, 1877, or any territorial or other interest in them as may be desired by said American Bell Telephone Company."

This vote and record are in my handwriting, and the record is attested by me as clerk.

Int. 33. Do you know the signatures of the parties who executed the assignment of the National Bell Telephone Company to the American Bell Telephone Company of May 8, 1880, recorded Liber R^{25}, page 105 of Transfers of Patents in the Patent Office, which I now show you, and if so, state; and also as to the seal which that instrument bears?

Ans. I do; they are the signatures of William H. Forbes who signed as president of the National Bell Telephone Company, and of William R. Driver who signed as treasurer. I am familiar with their handwriting as I have already testified. The seal attached to the instrument is the seal of the National Bell Telephone Company, which I am familiar with from my connection with that company as clerk and director.

[*Defendants' counsel waives the calling of W. P. Montague, the subscribing witness to the paper last put in evidence.*]

Int. 34. Will you state, by reference to the records, whether William H. Forbes was the president, and William R. Driver was the treasurer of the National Bell Telephone Company at the date of this instrument, May 8, 1880; and also state whether any and what ratification of it was made by the company?

Ans. By reference to the records of the National Bell Telephone Company, which were kept by me as clerk, and which are in my handwriting, I find that at the annual meeting of the stockholders of

the company, duly called and held at their office March 8, 1880, at which meeting a quorum was present, William H. Forbes was duly elected a director of the company, and George L. Bradley was duly elected treasurer of the company; and at a meeting of the directors of the National Bell Telephone Company held March 19, 1880, at which a quorum was present, George L. Bradley tendered his resignation as treasurer, and it was voted to accept the resignation. At this same meeting of direct rs, in accordance with Article 3 of the by-laws, William R. Driver was duly elected treasurer of the National Bell Telephone Company to fill the vacancy caused by the resignation of Mr. Bradley. At a meeting of the directors of said National Bell Telephone Company held March 27, 1880, at which a quorum was presen', William H. Forbes was duly elected president of the National Bell Telephone Company. In the record of the special meeting of the stockholders held June 21, 1880, to which I have already referred, appears the following: —

"The following papers; viz., two Transfers of Patents and other property from the National Bell Telephone Company to the American Bell Telephone Company, and a transfer and agreement between said National Bell Telephone Company and said American Bell Telephone Company, all dated May 8, 1880, were laid before the meeting and placed on file, and on motion of T. Sanders;

"*Voted*, That the aforesaid transfers and agreements be, and they hereby are, ratified and confirmed, and that the officers of this company be, and they hereby are, authorized to do all further acts convenient to carry into effect the votes passed at the stockholders' meeting held March 29, 1880."

Cross Examination resumed.

Cross-Int. 35. In your answer to Int. 32, in which you give a quotation from the minutes of the special meeting of the stockholders of the National Bell Telephone Company held June 21, 1880, your quotation commences with the word "voted," which I notice by referring to the minute book, is in the middle of a sentence. Please give me the context immediately preceding the word "voted."

Ans. It is as follows: "On motion of A. Cochrane, in pursuance of the agreement with the Bell Telephone Company, dated March 20, 1879, it was"; — then follows the vote already quoted.

me as best he could. There were about a dozen sets of instruments connected up and arranged around a platform, a switch-board, call-

DEPOSITION OF DANIEL M. ADEE.

Direct Examination by GEORGE L ROBERTS, Esq., *of Counsel for Complainants.*

BOSTON, Nov. 20, 1884.

Int. 1. State you name, age, residence, and occupation.

Ans. Daniel M. Adee; I am thirty-eight years old; I live in East Williamsburg, L. I., and am the adjuster of the Metropolitan Telephone and Telegraph Company of New York.

Int. 2. What are your general duties as adjuster, and what experience have you had with electrical subjects and instruments, more particularly telephonic apparatus?

Ans. As adjuster my duties are to look after the interests of the company generally in matters of disputed claims, settling those questions as they come up between the subscriber and the company. I have been connected with the telephone interest in various capacities since the earliest days of the telephone in New York City, which was the fall of 1878 or the beginning of 1879, which brought me in contact with the instruments in the matter of putting them up, taking them apart, adjusting them, etc. I have made the telephone a study, not so much in the line of duty as a matter of pleasure, experimenting on them with a view to improving their efficiency, in my own laboratory.

Int. 3. How extensive an acquaintance have you had with the use of telephones in this country?

Ans. I have witnessed the different changes that have been made in the instruments from time to time from the beginning, visiting different cities in New York, Pennsylvania, New Jersey, and Massachusetts. On Long Island I was acting in the capacity of superintendent of the Long Island district of the Metropolitan Telephone and Telegraph Company, which took in the whole of Long Island.

Int. 4. What is the usual mode of serving a community with telephones?

Ans. The district exchange system is the mode most universally used of serving the public, which consists of establishing a central office or offices in a city, which central office shall be the terminus

of subscribers to the system. These lines are connected upon call from any subscriber with any other party that shall subscribe to the said exchange.

Int. 5. How extensive is the telephone exchange system of the Metropolitan Telephone and Telegraph Company, in whose employ you are?

Ans. Their subscription list, I believe, numbers about 4,500. Their connections with adjacent cities and towns will offer upwards of 10,000 communications possible from any one subscriber's office in New York.

Int. 6. You speak of your acquaintance with the use of telephones in Pennsylvania; with what company are you most acquainted in that State, and what territory does it serve?

Ans. The Bell Telephone Company of Philadelphia. It serves the city of Philadelphia.

Int. 7. What telephone instruments are in use by the Metropolitan Telephone and Telegraph Company of New York, and by the Bell Telephone Company of Philadelphia?

Ans. The instruments known as the Bell telephone and the Blake carbon transmitter, furnished by the American Bell Telephone Company of Boston.

Int. 8. How early did you know of the existence of the Clay Commercial Telephone Company, one of the defendants in this case?

Ans. I think it was in May, 1884, that I first heard of their existence.

Int. 9. Have you since then investigated what that company has been doing in the way of putting out telephones for use; and if so when, and what have you ascertained?

Ans. I have. On September 3, 1884, I visited the electrical exhibition in Philadelphia. While there I saw the Clay Commercial Telephone Company's exhibit. While there I was introduced to a Mr. Bratton by one of the workmen there. He was the general manager of the Clay Commercial Telephone Company. He showed me the several instruments, taking them apart, and showing me each part of both transmitter and receiver, and explaining them to me as best he could. There were about a dozen sets of instruments connected up and arranged around a platform, a switch-board, call-

ing apparatus, etc. I talked through one set and to another within the building. Incidentally I mentioned to him that I was from New York, and connected with the telephone business; and he said that the company would, in all probability, extend their operations in New York and on Long Island very soon; that they were doing well in Philadelphia, and expected soon to extend their business all over the country. On Nov. 8, 1884, (I believe it was Nov. 8,) I again visited Philadelphia, and having obtained a list of their subscribers bearing date of Oct. 1, 1884, I proceeded to call upon one of their subscribers, the National Bank of the Republic. There I saw a set of instruments stamped "The property of the Clay Commercial Telephone Company, Clay patents, 1883." The receiver was also stamped "Clay Patents, 1883." Each of them was numbered and lettered. I opened the instruments and found them to correspond with those which I had been shown in the exhibition building on Sept. 3. On the 8th of November I also visited the Exchange of the Clay Commercial Telephone Company, and I saw there a telephone exchange with the usual apparatus, switch-boards, telephone instruments, etc., a cupola with cables running in; calls coming in and being answered in the usual manner by annunciator. On Nov. 12, I believe, I again visited Philadelphia, and taking the list of the Clay Telephone Company before mentioned, I called at a number of the offices of parties named therein, and called up others from these offices through the central office, making a memorandum of such offices from which I called, taking a memorandum of the numbers and imprints upon each instrument as nearly as I could, some being stamped poorly. I found the instruments in these offices to correspond in shape and form with each other and those seen at the exhibition. I also visited the Board of Brokers' Exchange, which is a private exchange, established by the Clay Commercial Telephone Company for the use of brokers exclusively, I am told. I saw there a switch-board of a capacity of fifty wires, thirteen sets of instruments, and two operators. I saw the operators making connections for those who came in and asked for them. The instruments were not all alike in this room. Some were without the combination of the bells. Others were the same as those mentioned before as seen at the exhibition.

Int. 10. Have you here with you the memoranda which you made of subscribers to the Clay Commercial Telephone Company, and if you have not, state, to the best of your recollection, how many such you visited, and the names of those you remember besides the National Bank of the Republic.

Ans. I have not. It was recopied and destroyed, I believe. I have not the copy with me, either. The names of the parties are not impressed upon my memory, but there were thirteen of them, I believe, whom I visited.

Int. 11. Have you examined the instruments now before you, and, if you have, how do they compare in details of construction with the instruments shown you by Mr. Bratton at the electrical exhibition, and with the instruments which you also examined at the National Bank of the Republic in Philadelphia, and with the other instruments which you saw at the several offices of subscribers to the Clay Commercial Telephone Company's Exchange, and with the instruments that you saw in use in that exchange?

Ans. I have. I see no difference in their construction.

[*Counsel for complainants puts in evidence the instruments referred to, and the same are marked "Exhibit Defendants' Transmitter," and "Exhibit Defendants' Receiver," respectively.*]

Int. 12. What part of this apparatus, Exhibit Defendants' Transmitter, contains the telephone transmitting instrument proper, and what adjuncts are also contained in the box, and provided for therein?

Ans. The upper part contains the electrodes, the carbon pencil and the metallic point. The lower portion of the box should contain the battery which locally passes through the transmitter; the magneto bells in this instance are contained in the transmitter compartment. In the same compartment is contained the switch for throwing in and out the local circuit. The working parts of the transmitter are attached to the cover or door of the upper compartment.

Cross Examination by FURMAN SHEPPARD, Esq., *of Counsel for Defendants.*

Cross-Int. 13. Under what telephone patents is the Metropolitan Telephone and Telegraph Company of New York (in whose employ you say you are) working?

Ans. Under the patents of Alexander Graham Bell, and I do not know how many others. There are many others I believe. I only know them as being the property of the American Bell Telephone Company of Boston, and furnished to us to use under license in New York.

Cross-Int. 14. At whose instance was it that you visited Philadelphia at the times mentioned by you, to investigate what the Clay Commercial Telephone Company has been doing?

Ans. The first instance, the 3d of September, my own, visiting the exhibition; in the second and third instances by the vice-president of the Metropolitan Telephone and Telegraph Company.

Cross-Int. 15. What is the local or territorial extent of the rights of the Metropolitan Telephone and Telegraph Company?

Ans. New York City, and thirty-three miles around it; that's the way I understand it.

Cross-Int. 16. What is the name of the vice-president to whom you referred?

Ans. Joseph P. Davis.

Cross-Int. 17. What was the specific object of your visit to each one of the subscribers to the Clay Commercial Company's Exchange?

Ans. To ascertain what they were doing, — what instruments they were using.

Cross-Int. 18. To ascertain for what purpose?

Ans. To give my evidence in this suit.

Cross-Int. 19. Did you confine or limit any communication you may have had with any of those subscribers, to an inquiry as to the nature of the instrument they were using?

Ans. I don't know that I had any conversation with any of them at all, except to ask them to allow me to use their instruments; and in one or two instances asked them how they worked.

Cross-Int. 20. Did you circulate any printed paper or pamphlet

among those subscribers, or address or cause to be addressed any such to them, or any of them?

Ans. None whatever.

Cross-Int. 21. Do you know, or have you been informed in any way, directly or indirectly, that any such pamphlet of any sort was mailed or addressed or sent to those subscribers, or any of them?

[*Objected to as inadmissible, the subject not being opened in the direct examination, and as otherwise inadmissible and incompetent.*]

Ans. I have heard that a pamphlet had been sent round; but I don't know where they were mailed from or who sent it.

Cross-Int. 22. When you visited the subscribers to the Clay Commercial Telephone Company's Exchange to ascertain what instruments they were using, did you not know that this suit had already been brought against that company?

Ans. No.

Cross-Int. 23. When did you first learn, or when were you first informed, or when did you first hear that this suit had been brought?

Ans. I do not know when it was. I do not know that I really knew of it until to-day. I don't know that I have been informed at all upon the subject.

Cross-Int. 24. In your visits to Philadelphia to see what the Clay Commercial Telephone Company was doing, and in your visits to the subscribers to their exchange, one of those visits being within the last twelve or thirteen days, and another being within the last eight or nine days, did you not hear in any way in Philadelphia, or learn from the vice-president, who sent you over there, that there was a suit pending by the Bell Company against the Clay Company?

Ans. I do not remember of anything having been said about there being a suit pending; that there would be a suit brought was my own inference from the nature of the business which I had in hand.

Cross-Int. 25. That there would be a suit brought by whom?

Ans. By the American Bell Telephone Company.

Cross-Int. 26. You have stated in your cross examination that the object of your visit to the subscribers of the Clay Commerial Telephone Company on the 8th and 12th of November, the present month, was to enable you to give your evidence in this suit, and also

that you really did not know until to-day that this suit had been brought. Will you please explain these statements more fully?

Ans. What I meant by that was this: that when this suit should be brought, — as it has been customary heretofore when I have had similar duties to perform to get the evidence before the suit was brought. As to the "to-day" — the "to-day" referred to there should be corrected to read in this way: Notice to come here to-day.

DANIEL M. ADEE.

Attest: CHAS. H. SWAN, *Special Examiner.*

DEPOSITION OF CHARLES R. CROSS.

Direct Examination by GEORGE L. ROBERTS, Esq., *of Counsel for Complainant.*

BOSTON, Nov. 22, 1884.

Int. 1. State your name, age, residence, and occupation.

Ans. Charles R. Cross; I am thirty-six years old; I live in Boston, and am Thayer Professor of Physics in the Massachusetts Institute of Technology.

Int. 2. How long and to what extent have you been engaged in the study of the physical sciences, and to what extent, if at all, have you been accustomed to make experiments in the several branches of physics, especially those relating to electricity and acoustics?

Ans. I have been an instructor at the Institute of Technology during the past fourteen years, and during that time I have been constantly engaged in the study of various branches of physics. During the past eleven years I have especially investigated the subjects of acoustics and certain branches of electricity. In the prosecution of my studies during this time I have constantly been engaged in the experimental study of the subjects mentioned, and have been practically familiar with all the apparatus ordinarily used by scientific men in the investigation of sound and electricity.

Int. 3. What attention have you given to the speaking telephone, and to its principles and mode of operation?

Ans. I have been familiar with the rise and development of the speaking telephone from its very beginning, having been in frequent communication with Prof. Alexander Graham Bell ever since the winter of 1873–74. I am familiar with Mr. Bell's patents, have investigated with great care the theory upon which these patents are based, and am practically familiar with the construction and use of the various forms of instruments constructed in accordance with said patents. During the past five years I have conducted a very extensive series of experiments relating to the different branches of telephony, in the capacity of expert for the American Bell Telephone Company.

Int. 4. Have you given attention to that form of telephonic transmitter which operates by varying the resistance of a circuit?

Ans. During the last five years I have given special attention to the theory and operation of variable-resistance battery transmitters. I have made a large series of original experiments and investigations upon the subject, more extensive than any that I have ever seen in print. I have carefully studied the distinctions which exist between variable-resistance battery transmitters and circuit-breakers, as well as the differences in the electrical and acoustic effects which they produce in the line wire and in the receiving telephone.

Int. 5. Have you heretofore testified as a witness in any cases in the courts of the United States upon the principles of the inventions set forth in patents and embodied in machines or apparatus?

Ans. I have done so frequently.

Int. 6. You say you have been familiar with Mr. Bell's patents. State whether or not among these patents are those which have been introduced in evidence in this case marked "Exhibit Bell Patent No. 174,465," and "Exhibit Bell Patent No. 186,787."

Ans. The patents No. 174,465 and No. 186,787 are among those which I have had frequent occasion to examine.

Int. 7. Referring to the patent No. 174,465, will you explain the mode of operation of the apparatus referred to in the fifth claim of the patent, explaining, as far as may be necessary, the character of sounds, their action upon the apparatus, and the manner in which the apparatus operates to produce the results which are ascribed to it in the patent?

Ans. The sensation of sound is produced by the action upon the ear of the vibrating particles of air which are set into a vibratory or to-and-fro motion by the vibrations of the sounding body. The primary impulse given by the sounding body to those particles of air immediately in contact with it is gradually transmitted from particle to particle, in consequence of the elasticity of the air or other medium through which the sound passes. In consequence of the mode of action of the elasticity of the air, the motion originally communicated to the particles of air in contact with the sounding body is not transferred instantaneously to all the other particles; but in consequence of their inertia, as the sounding body vibrates to and fro, a similar movement is impressed upon one after the other of the particles surrounding it. This to-and-fro motion of

the vibrating body generates a similar minute to-and-fro motion of the air particles, so that they are alternately crowded more closely together, and separated more widely from each other, thus producing alternate condensations and rarefactions in the air. It is to these alternate condensations and rarefactions that the term "sound wave" is given. It will be observed that each particle vibrates to and fro in a straight line in the direction in which the wave motion is propagated. If we consider that the vibration of the air particles is produced immediately by the vibration of the sounding body, we see that the motions of the air particles must be a perfect copy of the motions of the particles of the vibrating body. Such vibrations may differ in three separate ways, viz., in the extent of the path of the vibrating particle, in the frequency of its vibration, and in the character of its vibration. It is evident, in the first place, that the vibrating particle may, in its to-and-fro motion, traverse a longer or shorter path; in the second place, it may traverse this path a greater or less number of times in each second, that is, its rate of vibration may differ; in the third place, while traversing its path it may move according to different laws of acceleration or retardation of its velocity; for example, its acceleration during a part of its course may be and in some cases is constant, or the rate of acceleration may constantly change, and the law of its change may vary in different ways. To the changes in the motion thus caused, what I have called the peculiar character of the vibration is due. If we consider these three kinds of variation in their effect upon the senses, we find that variations in the extent of the path or amplitude of vibration of the particle determine, other things being the same, the loudness of the sound; the variations in the frequency of vibration determine the pitch of the sound; and variations in the character of the vibration determine what is known as the quality or *timbre* of the sound.

In the statements which I have just made I have spoken of the motion of a single particle; but it is evident from the mode of transmission of sound that all of the particles of the air through which the sound is conveyed partake of the various characteristics of vibration which I have discussed.

I have used the term "quality or *timbre*." Quality is that pecul-

iarity of a sound by which, independently of its pitch or loudness, we are enabled to determine the instrument by which the sound is produced; thus, for example, the note of a violin differs from the note of a flute in quality, even though the two are the same in pitch and loudness.

It is well known to scientific men that these differences in quality, which, as I have said, are due to differences in the character of the motions of the vibrating particle, are produced acoustically by the combination of a number of separate or partial tones, which can be shown to be produced when a particle is in vibration, and which partial tones differ in number, in pitch and in intensity or loudness, in accordance with differences in the character of the motion of the vibrating air particles.

The lowest of these partial tones is called the "fundamental," the other and higher notes "overtones." Hence it is evident that the quality of a sound depends upon the relative pitch, intensity and number of partial tones present. In a very few exceptional cases only the fundamental is present, and what is called a simple sound is produced. In general, the pitch of a note is determined by the fundamental, the overtones determining the quality.

I quote from a standard work on acoustics by Prof. W. F. Donkin, published, Oxford, 1870 (p. 11): —

"When we speak of the pitch of the note produced by a string or an organ pipe, we mean in fact the pitch of the gravest simple tone in the combination. This particular component is in general louder than any of the others, and is that on which attention is fixed. The others become associated with it by habit, and seem only to modify its character without destroying the unity of its pitch."

These facts, constituting what is known as Helmholtz's Theory of Quality, were first discovered by the physicist whose name he theory bears, and were published by him more than twenty years ago. The human voice owes its peculiar quality to the presence of great numbers of these partial tones; and very slight changes in the partial tones will produce very considerable changes in the voice.

I quote from the English translation (Ellis's) of Helmholtz's great work "*Die Lehre von den Tonempfindungen*": —

"Human speech employs these very qualitative varieties of tone in order to distinguish different letters" (p. 28).

. . . . . .

"On inquiring to what external physical difference in the waves of sound the different qualities of tone correspond, we must remember that the amplitude of the vibration determines the force or loudness, and the period of vibration the pitch. Quality of tone can, therefore, depend upon neither of these. The only possible hypothesis, therefore, is that the quality of tone should depend upon the manner in which the motion is performed within the period of each single vibration" (p. 28).

. . . . . .

"Every different quality of tone requires a different form of vibration" (p. 32).

From what I have said thus far, it will be seen that, in order to reproduce articulate speech, we must be able to reproduce in the air, vibrations which shall possess the same characteristics of pitch, intensity and quality — that is, of rate of vibration, amplitude of vibration, and character of vibration — which are possessed by the vibrating particles of air which are set in vibration directly by the organs of speech. If we can determine the speed and direction of motion of an air particle at each instant, and hence also the extent of its path, we can evidently impress upon it all three of the characteristics that I have mentioned; and hence can produce any desired sound at will.

In Mr. Bell's patent No. 174,465 a method is described by which the motions which are produced in the air at one place, the transmitting station, can be reproduced by an electrical method of intercommunication at the receiving station. By means of his invention he is able, by the use of certain electrical apparatus, to impress upon the particles of air at a distant place, the receiving station, motions substantially identical with those which are immediately impressed by the voice upon the particles of air at the transmitting station.

According to the specification, he effects this result by the use of the transmitter, which takes up from the air at the transmitting station the motions which are impressed upon it by the voice of the speaker, and the vibrating portion of which transmitter moves in substantial accordance with the movements of the air particles them-

selves. This transmitter, being connected with a line wire joining the two stations between which speech is to be transmitted, is enabled, by its electrical connection with that wire, to produce in it electrical variations which correspond to and are similar in form to the motions of the movable part of the transmitter, and hence to the motions of the air particles which have actuated the movable part of the transmitter. These electrical variations, in their turn, set in motion a movable part of a receiving instrument with which the line wire is connected, and, in their turn, produce in this movable part of the receiver vibrations corresponding to and similar in form to those electrical vibrations by which they are produced, and hence to the motions of the air particles at the transmitting station. The movable part of the receiving instrument, thus vibrating, impresses upon the air at the receiving station vibrations similar in form and corresponding to its own motions.

The motions thus produced in the air particles at the receiving station are therefore evidently similar in form and correspondent to the original vibrations impressed upon the air at the transmitting station by the voice of the speaker at that station. This being the case, it is evident, from what I have said, that the sound uttered by the speaker at the transmitting station will be reproduced at the receiving station.

It appears from these facts that Mr. Bell's apparatus consists essentially of a transmitter adapted to take up the vibrations of the air at the transmitting station; a line wire connecting the transmitting with the receiving station, together with a battery or some other form of electrical apparatus which is capable of furnishing a supply of electricity; which line wire shall serve to transmit the electrical variations produced by the transmitter from one station to the other; and a receiver which, actuated by the electrical variations thus transmitted by the line wire, shall be caused to reproduce the motions of the transmitter and of the air particles by which that transmitter is actuated. It is true that the receiving instrument may not always reproduce the vibrations of the air particles at the transmitting station in every minute detail, but the instrument is a speaking telephone only so far as it is adapted to reproduce those motions with substantial fidelity; and its practical construction and

operation must be such that these vibrations shall be substantially reproduced.

It is evident that when the transmitter is in operation, variations in the electrical current may take place in three ways, — there may be a variation in either the direction of the current, the rate or violence of change of the current, and the frequency of change of the current; and from these three kinds of variations similar variations in the direction, rate and frequency of change of the motion of the movable part of the receiver will result. And hence, from these different electrical variations, differences in the quality, intensity and pitch of the sound produced by the receiving instrument will follow. Therefore, to reproduce articulate speech or any other sound in all its characteristics of pitch, intensity and quality, it is necessary that the movable portion of the receiving instrument shall be constantly under the guidance of and controlled by the movable portion of the transmitting instrument; and in case this constant control is not exercised, and in precisely that degree in which it ceases to be exercised, the instrument becomes incapable of transmitting articulate speech.

No form of transmitter which operates by making and breaking an electrical circuit can possibly transmit articulate speech or any other sound in its different characteristics of pitch, intensity, and quality, for the reason that the constant control, of which I have spoken, is not exercised in such an instrument. With any circuit-breaking instrument the loudness and quality of the sound produced at the receiving station are dependent solely upon the physical construction and action of the receiving instrument itself, and of the battery or other source of electricity by which the transmitter is acted upon. The intensity and quality of the sound produced at the receiving station are, therefore, with such an instrument, entirely independent of the intensity and quality of the original sound produced at the transmitting station. It is for this reason that an instrument of this class, such as, for example, the well-known Reis instrument, operating in the manner described, is incapable of transmitting either intensity or quality, and hence is incapable of transmitting articulate speech.

As will be seen from what I have already said, the Reis trans-

mitter, or any other transmitter which operates by making and breaking the circuit, is capable of transmitting pitch, and pitch only.

The essential difference between the electrical changes produced by the Reis transmitter and the changes produced by the apparatus, Fig. 7 of the Bell patent No. 174,465, when spoken to, is that the action of the Reis apparatus serves to break up into successive and di-junctive fragments a current of substantially uniform strength. This is a merely intermittent current. The frequency of its intermittences is the same as the frequency of the air vibrations which give rise to what is known as the pitch of the sound acting upon the transmitter. The apparatus, Fig. 7 of Mr. Bell's patent, on the other hand, produces when spoken to a series of electrical changes which in their character correspond to and substantially copy the changes which take place in the air performing the sonorous vibrations to be transmitted. The apparatus of Reis was intended to produce mere intermittences, the frequency of which corresponded to the pitch of the sound transmitted. The apparatus of Bell, on the other hand, was not intended to produce intermittences; nor is its operation due to their production. The declared purpose of the invention is to produce electrical variations, which in their form copy the vibrations of the air. This is the distinction between the mode of operation of one apparatus and the mode of operation of the other. It is the employment of the electrical changes due to and constituting one mode of operation as distinguished from the other, that is insisted upon by Mr. Bell in his patent and specified in his claim. It is because Mr. Reis employed the one mode of operation that his apparatus is not a speaking telephone, and it is because Mr. Bell employed the other that his apparatus is.

There is also another reason which prevents a Reis transmitter or other circuit-breaking instrument from transmitting articulate speech; this is the effect of the interruptions of the current in producing a loud and disagreeable noise in the receiver, which of itself would be sufficient to overpower and obliterate those fine shades of variation upon which differences in quality depend.

In fact, this noise is so marked that an ordinary battery transmitter can be used as a telephonic call by so operating it as to cause it to actually make and break the electrical circuit. Under these cir-

cumstances, the noise which proceeds from the receiving instrument, which, when the transmitter is used in a normal and proper manner, can be heard only by one close to the instrument, is capable of being heard throughout a large room.

Int. 8. You have described the operation of a speaking telephone apparatus when transmitting speech as set forth in the specification of Mr. Bell's patent No. 174,465. Will you now state briefly what is the function and importance of the similarity between the vibrations of the air accompanying sounds uttered into the transmitter and the electrical undulations which are caused in the apparatus while transmitting speech, as particularly referred to in the fifth claim of Mr. Bell's said patent, which is as follows: —

"5. The method of and apparatus for transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth"?

Ans. It is because of this similarity that speech is transmitted. In a perfect instrument the motions of the receiver are both the effect and a copy of these electrical variations. Since these electrical variations are a copy of the motions of the transmitter, it follows that the motions of the receiver are a copy of those of the transmitter; if substantially this action takes place, speech is transmitted, otherwise speech is not transmitted.

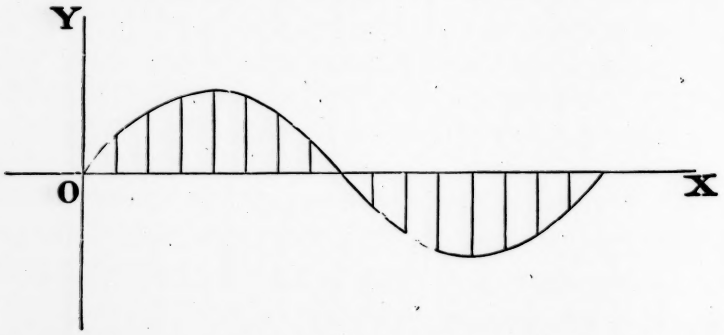
Int. 9. You speak of the sound waves, and explain the mode in which they are produced. Do you understand that the actual existence of these sound waves has been demonstrated, or is accepted as a fact by scientific men?

Ans. The existence of such sound waves has been accepted as a fact by scientific men for several hundred years. Within a few years past they have been visibly shown to exist, by a method which demonstrates the existence of alternate condensations and rarefactions to the eye.

Int. 10. Has any method of representing such waves been adopted; and if so, what is it?

Ans. It is customary among physicists to represent the motions of the particles of a sound wave, and also the variations in condensation and rarefaction at different points in a sound wave, by a

graphical method. I can best illustrate this by reference to a diagram which I produce, to be incorporated in my answer.



The curve in the diagram is what is called a sinusoidal curve, such as corresponds to the sound waves produced by a simple sound, consisting of a single note without overtones. Such a sound can be produced by a tuning fork, mounted on a resonant case, and bowed in a manner suitable for this purpose. O X is divided into a number of equal spaces, to represent equal periods of time. The length of these spaces is purely arbitrary. The distances from O to the beginning of any one of these divisions are called *abscissas*. From each of these points on O X, representing successive intervals of time, lines are drawn parallel to O Y, and proportional in their relative lengths to the distances of the particle from the point of rest at the successive periods of time.

In the case of the particle pursuing a simple vibration, these magnitudes will increase to a maximum, which will be attained at the instant when it reaches the extremity of its path; they will then diminish as it comes back to the starting point; and as it passes beyond it, moving in the other direction, they will be indicated by distances measured off below the line O X. Joining then the extremities of the perpendicular lines, we obtain a broken line somewhat resembling a curve; and if we put the perpendicular lines close enough together, the broken line joining their extremities becomes a curve. This curve is determined by the length of two sets of lines or distances, — the *abscissas* measured on O X, and the *ordinates* measured parallel to O Y. In the case stated, the

starting point is assumed to be in the middle of the path (*e. g.*, the position of a pendulum when at rest), and the motion is measured in both directions from it; *i. e.*, the curve is on both sides of the line, and part of the ordinates have one direction, part the other But the point from which the measurements are taken is purely arbitrary; and the line O X, which represents this point, might be placed lower down and tangent to the lowest part of the curve. In that case the curve would not change its character, but the ordinates would all be measured in one direction and on one side of O X. Algebraically expressed, they would all be + quantities, instead of being alternately + and — quantities, in the two branches of the curve; only the + quantities would be greater than shown in the diagram. In the case indicated by the diagram, we should consider that an increase in the length of the ordinates, in passing from one to the next, signified motion in one direction, and a decrease signified motion in the other direction. In this method of representation one set of lines, measured along O X, corresponds to the period in which the movement is executed, or its frequency; and the other, measured along O Y, to the amplitude or extent, and also to the direction of the motion; and these measurements express frequency, amplitude and direction. The same curve will represent the extent of rarefaction and of condensation of the air produced by the movement of the particles, and also, when correctly interpreted, the motion and the varying velocity of the particles.

It is from this habit of graphical expression that a vibration is commonly spoken of among physicists as having "form"; form of vibration is a phrase used to signify the "character" of a vibration, as I have explained it.

It must be remembered that this curve does not represent the path of the moving particle; that always moves to and fro in a straight line. This curve is merely a convenient form of expressing to the eye the character and variation of the motion.

I quote again from the work of Helmholtz: —

"To render the law of such motions more comprehensible to the eye than is possible by lengthy verbal descriptions, mathematicians and physicists are in the habit of applying a graphical method, which must be frequently employed in this work, and should therefore be well understood" (p. 29).

The writer then describes the method of drawing acoustic curves, and continues: —

"Physicists, then, having in their mind such curvilinear forms representing the law of the motion of sounding bodies, speak briefly of the *form of vibration* of a sounding body, and assert that *the quality of tone depends on the form of vibration*" (p. 32).

. . . . . .

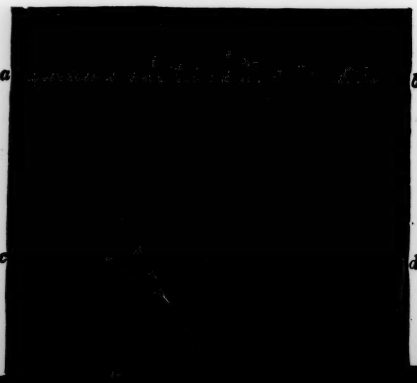
"I have by no means unfrequently found even physicists start on the false hypothesis that the vibrational form must exhibit little waves corresponding to the several audible upper partial tones" (p. 53).

. . . . . .

"The reader must bear in mind that when we apply the term 'compound' to the vibrations produced by a single musical instrument, the 'composition' has no existence except for our auditory perceptions or for mathematical theory. In reality, the motion of the particles of the air is not at all compound; it is quite simple, flowing from a single source" (p. 189).

Int. 11. If you can produce from any scientific work a diagram representing the manner in which overtones are combined with a fundamental to give quality to sound, different from that due to the fundamental alone, and representing the form given to the curve as the result of all the vibrations, will you do so, stating the source from which you derive it, and explaining as far as you think necessary the diagram?

Ans. The following diagram, taken from "Mayer on Sound," p. 153, represents the motion of a particle under the influence of sound waves: —

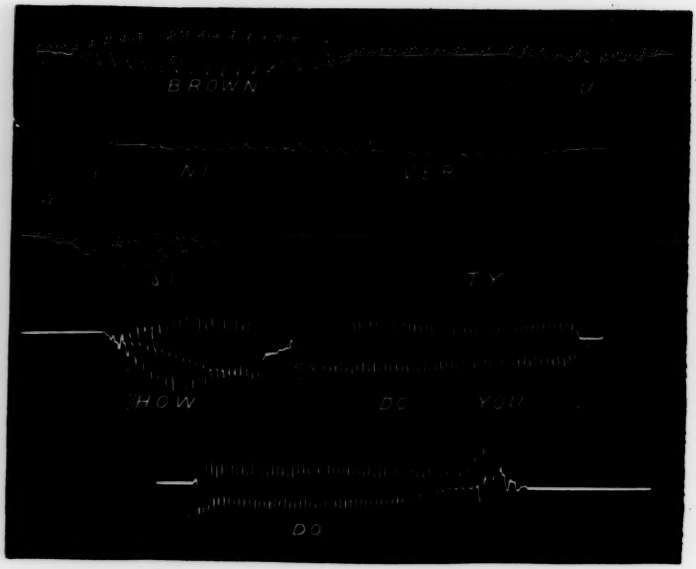


The curves at *a b* represent six sound waves of six simple sounds. When these are sounded together as fundamental and overtones, and with relative intensities corresponding to the amplitude of the curves, as drawn, so as to produce a sound having the quality due to this combination, the vibrational "form," as it is called, of the sound perceived by the ear is represented by the curve at *c d*. The set of vibrations which constitutes one complete vibration is shown twice between *c* and *d*. The entire "form" or character of this curve can be determined and controlled, as already stated, by determining or controlling for each point the length of the abscissa and of the ordinate for that point, or in other words, determining or controlling the elements of time or frequency, amplitude or intensity and direction; but it is obvious that it will require very many measurements of abscissas and ordinates to determine or control the "form" of each complete set of vibrations.

The curve representing one set of vibrations is about three inches long; and it is apparent, even to a casual observer, that by taking the ordinates as little as one eighth of an inch apart, we should miss the little twists, which most strikingly represent to the eye the "quality" or the effect of the overtones in this vibrational form, and which are equally important to the "quality" of the sound as perceived by the ear; and, as in the articulate speech of a woman, there are twenty-four thousand of these *complete* sets in a minute, it will be obvious that in order to reproduce this vibration the control must be exercised, not merely twenty-four thousand times a minute, but really without any interruption or cessation whatever.

Int. 12. If observations have been made upon the curves produced by spoken words, and you can produce a diagram representing the results of such observations, will you do so, giving the authority from which they were made?

Ans. The minute changes which take place during articulation are well shown in a series of curves made by Prof. E. W. Blake, Jr., of Brown University, and described in *Silliman's Journal* for July, 1878. These curves were produced by reflecting a ray of light from a mirror so attached to the plate of a speaking telephone that the vibrations of this plate were communicated to the mirror. The reflected ray is caused to act photographically upon a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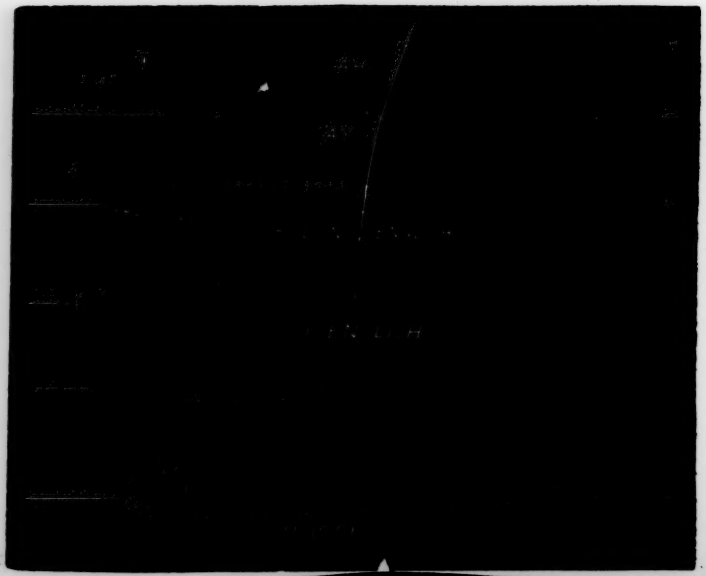


sensitized plate of glass, the mirror at the same time being caused to vibrate by the action of the voice upon the telephone plate. On rapidly moving the plate of glass in a direction at right angles to that in which the reflected ray was caused to vibrate by the vibrations of the mirror, a photographed representation of the complex vibrations of the mirror was produced.

In Prof. Blake's figures the vibrations characteristic of different vowels, and the rapidly changing vibrations produced in the case of a spoken sentence, are very beautifully shown. According to the statement made by Prof. Blake in the article referred to, the vibrations are magnified in the accompanying cuts one hundred and twelve times. Notwithstanding the accuracy of Prof. Blake's drawings, the mere thickness of the lines in the woodcut is sufficient to obliterate many of the more delicate variations in those vibrations which characterize articulate speech.

Int. 13. Referring again to the first Bell patent, No. 174,465, to which your attention has been called, will you state what the moving parts are which you have referred to as being put in motion by sound waves, or by variations of currents produced by sound waves?

Ans. In Fig. 7 the transmitter possesses a movable armature, *c*, one end of which is hinged, while the other is so attached to a membrane at *a* that when this membrane is set in vibration by the utterance of a sound into the cone A, the armature shall be caused to take up the vibrations of the membrane. By the vibration of this armature, as it approaches nearer to or recedes from the pole of the electro-magnet *b*, in accordance with the well-known laws of magneto-electric induction, electrical undulations or waves are produced in and transmitted by the line wire *e*. The receiving instrument which is in electrical connection with the line wire possesses an electro-magnet *f*, whose magnetic strength varies in accordance with the electrical variations produced in the line wire in the manner described. In front of this electro-magnet of the receiver, and opposite its pole, is a vibratory armature of inductive metal, hinged at *k*, and connected at *i* with a membrane stretched over the larger end of the cone L, so that variations in the magnetic strength of the electro-magnet *f*, produced by electrical variations in the line wire *e*, produce variations in the armature *h*, and consequently in the

attached membrane, so that this attached membrane vibrates in correspondence with the motions of the membrane of the transmitting instrument, and therefore in correspondence with the vibrations of the voice by which the membrane of the transmitter is actuated. I should have said that the vibrating armatures of both the transmitting and receiving instruments are of iron or other inductive metal; and I would also call attention to the fact that the hinged end of each of these vibratory armatures is in magnetic connection with that pole of the electro-magnet which is farthest from the vibrating part of the armature itself; this mode of connection serving to increase to a certain degree the magnetic strength of the apparatus.

Int. 14. Will you explain a little more in detail the functions of the battery represented in Fig. 7 of the Bell patent of which you have been speaking, and the manner in which the undulations in the current are produced in the apparatus represented in that figure, and in what way the undulatory current acts in the receiving instrument to produce the proper results?

Ans. The magnets *b* and *f* in Fig. 7 are electro-magnets, having soft iron cores, which cores are magnetic only when a current of electricity is passing through the coils surrounding them. The object of the battery shown in Fig. 7 is simply to produce this current, which shall cause the cores to be kept magnetized. The armature *c* of the transmitter, which is of iron or other inductive metal, will, as it moves to and fro, alternately increase and diminish the magnetic strength of the magnet *b*. These variations of magnetic strength will correspond to the various changes in motion of the vibrating armature. In accordance with the well-known laws of magneto-induction, as discovered by Faraday, every change in the magnetic strength of the core of the electro-magnet *b* will produce corresponding changes in the current of electricity which passes through the line wire *e*. These variations in the strength of the current will cause corresponding variations in the magnetic strength of the electro-magnet *f*, and the variations in the strength of the magnet will act immediately upon the vibratory armature at *h*. An increase of strength in the magnet *f* will cause the armature to approach to the magnet, while diminution of magnetic strength will allow the armature, under the influence of the tension of the membrane to

which it is attached, to recede farther from the pole *f*. Hence, under the influence of the varying magnetic strength of *f*, the vibratory armature at *h* will execute vibrations corresponding to these changes in magnetic strength, and therefore corresponding to the changes in the electric current in the line wire *e*, to the changes in the magnetic strength of the magnet *b*, and therefore corresponding to the variations in the motion of the vibratory armature at *c*, when moved by the vibrations of the membrane with which it is in contact. The membrane of the receiving instrument at *i* will therefore vibrate in correspondence with the membrane *a* of the transmitting instrument.

Int. 15. Please state briefly the principal scientific facts which you find set forth, and correctly set forth, in Mr. Bell's patent No. 174,465, of March 7, 1876, with reference to the apparatus shown in Fig. 7, and its operation, and which bear upon the question whether the patent, so far as that apparatus is concerned, is a patent for an electrical speaking telephone.

Ans. The speaking telephone is shown in Fig. 7 of the patent. In the body of the specification and in the claim, the patentee describes the nature of the operation which will take place when a sound is uttered into the transmitter by the human voice. I know, as a matter of scientific knowledge, that when spoken to this is the kind of operation which it theoretically will perform, and the only kind of operation which it theoretically can perform.

The patentee then asserts the consequence of that operation with that apparatus to be that a similar sound to that uttered into the transmitter is then heard to proceed from the receiver. This action is theoretically the necessary consequence of this operation of the apparatus. I know from actual trial that this operation would be so well performed by a set of instruments constructed according to the instructions of the patent, and without further invention, that the listener at the receiving end will recognize and understand the words spoken at the transmitting end.

That feature to which the most prominence is given in the specification is the similarity of form between the sound vibrations which actuate the instrument and the electrical undulations due to them. This is expressly mentioned in the following sentences of the specification: "These undulations are similar in form to the air vibrations

caused by the sound — that is, they are represented graphically by similar curves."

This is the only feature specifically mentioned in the claim, which reads as follows: —

"5. The method of, and apparatus for, transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth."

This feature of similarity in form between the electrical undulations and the air vibrations producing them secures the transmission of quality. It has no purpose, function or effect, except the transmission of quality, which includes articulate speech. This correspondence of form is the essential electrical novelty which distinguishes this apparatus from all others known to the community before it.

Int. 16. Do you find any mode suggested in the patent as an alternative one to that you have described, of producing the variations or undulations in the current between the transmitter and receiver; if so, will you quote from the specification the language which refers to such other mode?

Ans. It was well known to electricians, long before the date of Mr. Bell's first patent, that the strength of an electrical current can be varied, either by increasing the electro-motive force of the source of electricity or by diminishing the resistance of the circuit, and conversely, in accordance with the well-known law of Ohm,

$$\text{Strength of Current} = \frac{\text{Electro-motive Force}}{\text{Resistance of Circuit.}}$$

In the apparatus which I have described, Mr. Bell explains a mode of producing these electrical undulations by varying the electro-motive force. He also clearly recognizes the possibility of producing such undulations by varying the resistance of the circuit. In his specification No. 174,465, I find the following: —

"Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit. . . . The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current. The external resistance may also be varied. For instance, let mercury or some other liquid

form part of a voltaic circuit, then the more deeply the conducting wire is immersed in the mercury or other liquid the less resistance does the liquid offer to the passage of the current. Hence, the vibration of the conducting wire in mercury or other liquid included in the circuit occasions undulations in the current. The vertical vibrations of the elements of a battery in the liquid in which they are immersed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery."

Int. 17. If electricians have been in the habit of stating, in algebraic terms, the law to which you have referred, will you give the form of expression which has been used, explaining the symbols, and state how long that law has been known, and whether or not it is one which has been found of use in the practical application of electricity?

Ans. The law of Ohm is usually expressed by a formu'a $C = \frac{E}{R}$, in which C is the strength of the current; E the electro-motive force, that is, the force producing the current; and R the total resistance of the circuit. Ohm's law was, if I recollect rightly, first stated by him in the year 1827. For the last thirty years its importance has been fully recognized by physicists, and it has been applied by constructors of electrical apparatus in determining the dimensions and arrangement of the different parts of such apparatus.

Int. 18. In your judgment, does the substitution of one of these ways of varying the current for the other substantially change the character of the described apparatus as an apparatus for transmitting sounds, or substantially change the method by which sounds are transmitted or reproduced?

Ans. Speaking as a scientific man, I should say that it does not.

Int. 19. Have you examined and tested the instruments marked "Exhibit Defendants' Transmitter" and "Exhibit Defendants' Receiver" in this case? If so, for what purpose do you find them to be adapted, and what has been the result of your tests with them?

Ans. I have examined and tested the instruments referred to, namely, Exhibit Defendants' Transmitter and Exhibit Defendants' Receiver, and I find that they are, from their construction and method of operation, adapted, when suitably connected with a battery, to transmit articulate speech. I have in fact so connected them, and transmitted articulate speech by means of them.

Int. 20. When so connected and used for that purpose, what substantial likeness, if any, does the apparatus thus constituted, and the method by which it operates to transmit speech, bear to the apparatus and method described in the patent to Bell of which you have been speaking, and referred to in the fifth claim thereof; and in making this comparison, state whether or not in your judgment the defendants' said instruments, when so used, embody the invention described in said patent and referred to in said claim?

Ans. The apparatus to which I have referred in my last answer, Exhibit Defendants' Transmitter and Exhibit Defendants' Receiver, when connected and so operated as to transmit articulate speech, use the method invented by Mr. Bell, and described in his specification No. 174,465, for transmitting vocal or other sounds telegraphically, by causing electrical undulations similar in form to the vibrations of the air accompanying such sound. The instruments in question most certainly embody the invention which Mr. Bell describes in his specification referred to, and when used in the transmission of articulate speech constitute an apparatus which is substantially that described by him in his said patent in connection with Fig. 7 of the drawings and referred to in the fifth claim.

Int. 21. In the operation of transmitting speech in the defendants' apparatus, what is the importance of causing the electrical undulations to be similar in form to the sound waves?

Ans. Precisely the importance which is indicated in my answer to Int. 8. Any departure from similarity impairs the character of the speech to the extent to which it occurs; and when that departure or any extraneous disturbance reaches a certain point, the sounds at the receiver cease to be intelligible as speech.

Int. 22. Will you compare these instruments, when so connected and used, with Mr. Bell's apparatus, to which you have referred, pointing out the functions and mode of operation of the several parts? And if you find that these instruments differ specifically from the Bell apparatus, explain the nature of the differences, and give your judgment as to their affecting the substantial likeness of this apparatus to the Bell apparatus and its method of operation.

Ans. In Mr. Bell's patent No. 174,465, I find a transmitting instrument, a receiving instrument, a line wire connecting these, and a

battery or other source of electricity. In the apparatus described, the transmitter possesses a movable part, which is capable of being set in vibration by the agency of the voice. This movable part is so arranged that it shall cause electrical variations in the current traversing the line wire. The receiver is so arranged that the variations of current referred to shall communicate motion to a movable part, which shall in its turn communicate motion to the air about it. As I have already shown at some length, the vibrations of this movable portion, when actuated by the sound waves produced by the voice, correspond to these in form, and by their action upon the receiving instrument cause it to vibrate in a similar manner, and hence produce corresponding vibrations in the air about the receiver. The function of the transmitter, it is evident, is simply to produce in the line wire electrical undulations similar in form to the vibrations of the air particles through whose agency they are produced. The function of the receiver is simply to translate, so to speak, the electrical undulations produced by the transmitting instrument and conveyed to the receiving instrument by the line wire, into vibrations of the air at the receiving instrument. Mr. Bell indicates that these electrical undulations may be produced either by varying the electromotive force of the current or by varying the resistance of the circuit.

In the exhibits specified I find a transmitter and a receiver, which when placed in electrical connection with each other by means of a line wire, and provided with a battery as a source of electricity, are adapted to transmit, and will transmit, articulate speech from one station to another.

In the defendants' battery transmitter I find an instrument, which, from its construction, is adapted to produce, and, when properly operated by the voice, will produce, electrical undulations in the current traversing the circuit, similar in form to the air waves by which these electrical variations are produced.

In the defendants' receiver I find an instrument which is adapted to produce vibrations in the air similar in form to vibrations originally produced in the air at the transmitting station by the voice, as I have already explained. The defendants' apparatus, like the appa- a transmitter, which, from its

construction, is adapted to produce electrical undulations as described, and a receiver which is adapted to retranslate these electrical undulations into vibrations of the air.

The defendants' battery transmitter adopts one of the modes mentioned by Mr. Bell as suitable for the production of electrical undulations similar in form to the air waves produced by the voice, namely, by varying the resistance of the circuit. The precise means adopted in the defendants' transmitter for varying the resistance of the circuit is different from the particular means referred to by Mr. Bell, inasmuch as it utilizes the property, possessed by various substances, of variation in resistance with variation in pressure.

In my opinion, however, the adoption of one rather than another particular way of varying the resistance of the circuit does not materially affect the substantial likeness of the apparatus of Mr. Bell and defendants, or its method of operation.

Int. 23. Will you state whether the fact to which you refer, that the resistance of substances may be varied by pressure, was one known before the date of Mr. Bell's patent, and recognized in the construction of electrical apparatus; and if you can refer to any electrical works of authority, where this fact is referred to, will you do so, and quote the references to the fact?

Ans. It was known long before the date of Mr. Bell's patent that the resistance of a circuit is varied, without being broken, by variations in the intimacy of contact or amount of pressure between two electrodes in contact, from one to the other of which a current is passing. This fact was noted and recorded by Du Moncel in his book, "Applications de l'Électricité," Vol. II. p. 246, edition of 1856, published at Paris in that year. In the "Comptes Rendus" for July, 1874, a communication from the same writer described some experiments as to the resistance offered to the current in passing from one electrode to another, in the case where one was a good conductor and the other a poor conductor, and showed that a moderate increase of pressure at the contacts would materially increase the conductivity, and thereby the current; and he gave his explanation for this phenomena.

In Du Moncel, "Applications de l'Électricité," ed. 1856, Vol. I. p. 246, I find the following: —

"Une chose assez curieuse, et qui paraît être au premier abord en contradiction avec la théorie que l'on s'est faite de l'électricité, c'est que la plus ou moins grande pression exercée entre les pièces de contact des interrupteurs influe considérablement sur l'intensité du courant qui les traverse. Cela tient souvent à ce que les métaux de l'interrupteur ne sont pas toujours dans un état parfait de décapage au point de contact, mais peut-être aussi à une cause physique encore mal appréciée. Ce qui est certain, c'est que, dans les interrupteurs où la pièce mobile de contact est sollicitée par une force extrêmement minime, le courante éprouve souvent des affaiblissement assez notables pour faire manquer la réaction électrique qu'on attend d'eux."

Which I translate as follows: —

"A somewhat curious fact, which at first sight appears to be in contradiction to the views ordinarily received as to the action of electricity, is that the greater or less pressure exercised between the contact pieces of interrupters has an important influence upon the strength of the current which traverses them. This often happens, because the metal of the interrupter is not perfectly free from rust at the point of contact, but perhaps also because of a physical cause as yet but little appreciated. This is certain, that with interrupters in which a movable contact piece is acted upon by a very slight pressure, the current often suffers such an enfeeblement as to cause a failure in the electrical action which was expected."

The same writer describes, in the "Comptes Rendus" for July 6, 1874, a series of experiments in which he measured the current in a circuit, part of which consisted of a platinum electrode and a piece of wood, more or less damp, kept in constant contact, but with varying pressure, and says, p. 41, in an article entitled "Récherches sur les transmissions électriques à travers les corps ligneux," as follows: —

"Les expériences que j'avais à faire pour avoir une constation exacte des effets produits, étaient assez délicates, car une foule de causes étrangères peuvent intervenir, et changer les résultats fournis. Ainsi le dégré de serrage des plaques métalliques de communication avec le bois, son isolement plus ou moins parfait du sol et des murs de l'appartement, où l'on expérimente, la grandeur des surfaces mises en communication avec le circuit métallique, la masse du bois, l'état plus ou moins humide d l'air du cabinet des expériences, le

contact fortuit des doigts sur les fils de communication avec le galvanomètre, et l'état d'isolement de ces fils sont autant de causes qui peuvent modifier les résultats que l'on obtient.

. . . . . .

"6. Que le dégré de la pression de la plaque de platine contre le bois a tellement influé sur l'intensité du courant ainsi transmis, qu' étant de 12 dégrés avec un serrage maximum elle est devenue à zéro quand la plaque était abandonée à son propre poids, et 5 dégrés seulement avec un faible serrage."

This I translate as follows: —

"The experiments that I have had to make in order to have an exact proof of the effects produced were very delicate, because a number of foreign elements might enter and change the results. Thus *the amount of pressure upon the metallic plates in communication with the wood*, its more or less perfect insulation from the earth or the walls of the room, the size of the surfaces put in communication with the metallic circuit, the mass of the wood, the greater or less humidity of the air of the experimenting room, the accidental contact of the fingers with the wires leading to the galvanometer, and the condition of the insulation of these wires, were causes which might modify the results that would be obtained.

. . . . . .

"6. That the amount of the pressure of the platinum plate against the wood has so much influence on the strength of the current thus transmitted, that from twelve degrees, with a maximum pressure, it became reduced to zero when the plate was pressed only by its own weight, and to five degrees only with a slight pressure."

In Du Moncel's "Traité de Telegraphie Électrique," Paris, 1864, Part IV. p. 559, in speaking of apparatus designed to establish electrical contact, the author says: —

"L'expérience montre que plus la pression des contacts est grande, plus est énergique l'intensité du courant qui les traverse."

That is, in English —

"Experiment shows that the greater the pressure of the contact pieces, the stronger is the current passing through them."

That fact was also consta[illegible]acted upon in the practical use of electrical apparatus; care was always taken that contacts should be firm and with considerable pressure, for otherwise the full and desired strength of current was not obtained.

Int. 24. State more particularly what you have meant by variations in pressure, as applied to the defendants' apparatus, and as applied to the experiments and statements of Du Moncel, which you have quoted.

Ans. By the variations in pressure which I have mentioned, I mean those variations because of which the contact pieces of hard carbon and platinum in the transmitter are pressed more or less closely together. I do not refer to these variations of pressure as producing change throughout the whole mass of the contact pieces, but simply to those variations which occur at the surfaces in contact. These are simply variations in the force by which the contact pieces are pressed together; and such variations produce variations in the electrical resistance of the joint thus made. The greater the pressure the more intimate is the contact and the less the electrical resistance, and *vice versa*.

Int. 25. What name has been given to that part of a battery telephone which is made to operate by variations in pressure between contact pieces of carbon or other conductor, and what familiar instance of such a telephone can you mention?

In this connection also you may further explain the principle of its operation.

Ans. That variety of the speaking telephone transmitter which is referred to in the question is known as the articulating microphone, or, more generally, simply as the microphone. The form best known in commercial use is what is called the "Blake transmitter," invented by Mr. Francis Blake, and manufactured for general use by the Bell Telephone Company in the fall of 1878, and now universally employed in the United States.

The microphone consists physically of two electrodes placed normally in contact, with a slight pressure, and forming part of a circuit supplied with a current from a battery. A single Leclanché cell is generally employed in practice, though in some of my experiments with certain forms of microphone having large contact surfaces I have used as many as four Leclanché cells or two Bunsen.

One of the electrodes of the microphone is so arranged that when spoken to it will take up the vibrational movement of the sound waves. The other electrode is mounted so as not to be similarly

affected by them; and the consequence is that the former electrode moves relatively to the latter. This motion of one electrode relatively to the other is excessively minute; but it is sufficient to so affect the current in the circuit that a magneto-receiver of the ordinary improved commercial form, conforming to the principles indicated by Fig. 7 of Mr. Bell's first patent, will audibly repeat the words uttered into the transmitter.

To aid in this operation of the transmitter, the electrode which is designed to be more directly vibrated by the voice is preferably made of such a shape as to offer of itself some considerable surface to the sound waves, or else is mounted upon an extended surface, such as a metallic diaphragm or a thin board.

There seems to be hardly any limit to the forms which may be given to the microphone. Many materials, including the ordinary metals, can be used for the electrodes; but it has always been the practice to make one of them at least of carbon, because this material gives far better results than any other hitherto used. In the Blake transmitter, one electrode is a hemisphere of platinum about $\frac{1}{20}$ of an inch in diameter, slightly flattened, while the other offers a plane surface of hard gas carbon, artificially hardened and polished.

The back electrode, or anvil electrode, as it is sometimes called, is either rigidly held or is more often so mounted that it can yield somewhat, but not too readily, to the motions of the electrode directly acted on by the voice. The desired normal contact and pressure in the latter case are commonly obtained by the use of a spring or by gravity and sometimes in other ways.

A speaking telephone on this principle was described in papers filed in the Patent Office by Mr. Berliner, and by Mr. Edison, in 1877. In 1878, Prof. Hughes reinvented it, approaching the problem from a somewhat different direction, viz., from vibrations mechanically excited by scratching with a pencil, or by the tramp of a fly, and passing thence to those excited by sonorous waves in the air. He first published a description of his instrument in a paper read before the Royal Society, London, May 9, 1878. Notices of it are to be found in the *Scientific American* Supplement, June 8, 1878, and elsewhere.

The action of the microphone in transmitting articulate speech is

as follows: The sound waves produced by the voice impress their vibrations directly upon the front or "hammer" electrode, and by virtue of the inertia of the back or "anvil" electrode, as already explained, the vibrations of the first electrode cause corresponding variations in pressure between it and the second electrode. These variations of pressure, by varying the electrical resistance of the microphone contact, create electrical undulations in the current similar in form to the sound waves producing them; and when these electrical undulations pass through the coils of the electromagnet of the receiving telephone they cause corresponding variations in the magnetic state of the core, and thus set the diaphragm into vibrations corresponding to such magnetic changes. By these vibrations of the diaphragm air waves are finally produced at the receiving station similar in form to those originally produced by the voice of the speaker at the transmitting station.

Int. 26. Did you testify as an expert in the case of the American Bell Telephone Company *et al. v.* Albert L. Spencer *et al.*, in the United States Circuit Court within the District of Massachusetts, wherein a decision has been rendered for the complainants; and were you familiar with the telephonic apparatus therein complained of, and held by the Court to infringe upon the Bell patents aforesaid; if so, what was the character of the transmitting instrument to which the decision in that case applied?

Ans. I did testify as an expert for the complainants in the Spencer case referred to, and became familiar with the telephonic apparatus complained of therein. The transmitter of that apparatus was an articulating microphone, which operated in the manner and according to the method I have described in my last preceding answer.

Int. 27. Did you testify as an expert in the case of the American Bell Telephone Company *v.* Amos E. Dolbear *et al.*, in the United States Circuit Court within the District of Massachusetts, wherein a decision has also been rendered for the complainants; and were you familiar with the telephonic apparatus therein complained of, and held by the Court to infringe upon the Bell patent No. 174,465; if so, what was the character of the transmitting instrument belonging to the apparatus to which the decision in that case applied?

Ans. I testified in the case referred to, and became familiar with the apparatus in that case. The transmitter was an articulating microphone, and it operated in the manner which I have already described.

Int. 28. You have said that the defendants' transmitter produces electrical undulations by utilizing the property of variation in resistance with variation in pressure, possessed by various substances. Please compare the construction and mode of operation of the defendants' transmitter with the construction and mode of operation of the articulating microphone which you have explained, and point out their substantial likenesses and differences.

Ans. In the Exhibit Defendants' Transmitter, I find a piece of platinum, which is firmly attached to the centre of a thin wooden diaphram. This constitutes the hammer electrode of the microphone. Against this piece of platinum there presses a cylindrical piece of hard carbon, which is carried by a pendulous rod of iron. This rod is pivoted to a brass arm at the upper part of the instrument, so that, when the transmitter is in its normal position, the iron bar, with the attached carbon, shall hang nearly, but not quite, vertical, the pivot from which the rod is suspended being so placed that the pressure of the platinum electrode upon the carbon electrode shall push the rod that is attached to the latter slightly aside from a vertical position. The normal pressure between the two electrodes will evidently be greater in proportion as the deflection of the rod from the vertical is increased. This inclination, and consequently the normal pressure, can be varied by means of an adjusting screw, which moves the axis of suspension of the rod, so that this axis may be either nearer to or farther from the plane of the diaphragm: in the former case increasing the normal pressure, and in the latter case diminishing it. The joint between the pieces of platinum and carbon is included in the battery circuit. When the diaphragm is set into operation by the sound of the voice uttered against it, the first or hammer electrode necessarily vibrates with the diaphragm. These vibrations of the hammer electrode cause corresponding variations to be produced in the pressure between the hammer and anvil electrodes, as I have already explained in my answer to Int. 25. These variations in pressure produce corresponding variations in the

strength of the current flowing in the line wire. The contact pieces of platinum and carbon in the defendants' transmitter, when mounted as described, constitute a microphone, and operate in the manner which I have already explained in my answer to Int. 25.

It is customary in the practical use of microphone transmitters to employ an electrical apparatus known as an induction coil, in order to overcome more effectively the resistance of the circuit. An induction coil, as so used, consists of two entirely separate coils of wire, having a common axial core of soft iron. One of these coils is wound upon the outside of the other. The inner coil is composed of a small number of turns of rather coarse wire, and is called the primary coil. The outer coil is composed of a large number of turns of fine wire, and is called the secondary coil. The operation of the induction coil is such that, whenever a current of electricity of varying strength is caused to pass through the primary coil, if the ends of the secondary coil are connected with each other (either directly, or indirectly by means of a circuit which may contain a receiving telephone), a current possessing similar variations will flow through the secondary circuit. But in accordance with well-known electrical principles, the current thus generated in the secondary coil will have a far greater power of overcoming resistance than is possessed by the original current in the primary coil. The induction coil thus acts as a sort of electrical lever. In the use of the induction coil with a microphone transmitter, the transmitter with the battery is placed in circuit with the primary coil of the induction coil. The secondary coil is placed in circuit with the line wire and the receiving instrument. Such an induction coil is universally used in the Blake transmitter when employed for commercial purposes, and was present in the transmitter of the defendants in the Spencer case, and in the Dolbear case to which I have heretofore r[illegible]erred. The induction coil in microphone transmitters is usually p[illegible]ed in some convenient position within the box holding the appa[illegible]us. In the Exhibit Defendants' Transmitter the wire coils are placed upon the pendulous iron rod by which the carbon electrode is carried, so that this iron rod constitutes the core of the induction coil. As thus placed, the coil, in virtue of its mass, gives increased inertia to the anvil electrode,

and also for a given inclination of the bar, increases the normal pressure between the electrodes.

Int. 29. Have you examined Letters Patent of the United States, No. 298,286, dated May 6, 1884, and granted to the Clay Commercial Telephone Company as the assignee of Henry Clay, for Improvements in Telephonic Transmitters; and do you understand the construction and mode of operation of the apparatus therein described and shown? If so, will you compare that form of the apparatus which is delineated upon sheet 1 of the drawings of this patent with the Exhibit Defendants' Transmitter; that is to say, so much of it as constitutes the transmitting member of the telephone, and state how you find the apparatus, so compared, to correspond or differ substantially in construction and mode of operation?

Ans. I have examined a Patent Office copy of the patent referred to, and understand the construction and mode of operation of the apparatus described and shown therein. The apparatus of the Exhibit Defendants' Transmitter is substantially identical with the apparatus described in the patent referred to, and shown in detail upon Sheet 1 of the drawings, Figs. 1, 2, 3 and 4. There are some minor differences in the form and arrangement of specific parts, but these differences in no way affect the nature or mode of operation of the microphone in the transmitter. In the Exhibit Defendants' Transmitter the platinum electrode is a horizontal wire, and the carbon electrode a pencil with its axis vertical, while in the figures of the patent the platinum electrode, *b*, is a vertical strip of that metal; and the carbon electrode, D, is a horizontal pencil of that material. Also, in the instrument of the exhibit the carbon electrode is permanently attached to the pendulous bar, while in the patent the carbon electrode, D, is loose upon its supports. Also, the specific means of varying the normal contact pressure between the electrodes are slightly different in the two cases, owing to a difference in the manner of suspension of the pendulous bar. The induction coil is found, and in the same position, both in the apparatus of the patent and of the exhibit.

The mode of operation of the microphone in the Exhibit Defendants' Transmitter is identical with the mode of operation of the microphone of the patent. I find this recognized in the description of

that operation, as given in the specification of this patent, from which I quote as follows; —

"My invention has relation to that class of telephonic transmitters wherein the changes of pressure upon a carbon block cause it to offer different resistances to the passage of an electric current, so as to vary its strength in unison with the rise and fall of vocal utterances; and it has for its object to simplify the construction of the instrument, make it more compact and durable, regulate the force of contact of the electrodes, and increase the electro-motive force of the induced currents."

[*Counsel for complainants puts in evidence the patent just referred to, and the same is marked "Exhibit Clay Patent, No. 298,286, Chas. H. Swan, Special Examiner."*]

Int. 30. In the answer of the defendant, the Clay Commercial Telephone Company, it avers that the telephones made, used and sold by it have been made and constructed under, and in pursuance of, certain Letters Patent of the United States, issued and granted to Henry Clay; and among these is specified Letters Patent No. 288,017, dated Nov. 6, 1883, for Improvements in Telephonic Transmitters, and Letters Patent No. 280,580, dated July 3, 1883, for Improvements in Transmitters for Telephones. Have you examined these patents, and do you understand the construction and mode of operation of the apparatus therein described and shown respectively; and, if so, will you state briefly what is the character and mode of operation of the telephonic transmitters in which the improvements therein specified are embodied?

Ans. I have examined the patents referred to, and understand the construction and mode of operation of the apparatus therein described. The apparatus of both patents is a microphone. Their substantial construction and their mode of operation is identical with that of the microphone, as explained in my answer to Int. 25. As I have said in that answer, there is hardly any limit to the number of special forms which may be given to the microphone. The operation of the microphone, which I have described in that answer, is recognized in both of the Clay patents, No. 280,580 and No. 288,017, and is expressly stated in the specification of the latter of these patents, from which I quote as follows: —

"My invention has relation to that class of telephonic transmitters wherein the variations of pressure upon a carbon block vary the resistance therein to the passage of an electric current, to vary its strength in unison with the vibrations caused by vocal utterances."

The likeness existing between the Exhibit Defendants' Transmitter and the apparatus described in the Clay patents, No. 280,580 and No. 288,017, is only the broad one arising from the fact that all three of them are microphones. The instrument Exhibit Defendants' Transmitter does not contain the specific improvements which are mentioned and referred to in the claims of either of the two Clay patents, No. 280,580 and No. 288,017.

Int. 31. Is the mode of securing and maintaining contact between the electrodes of the microphone transmitter, by attaching the anvil electrode to a pendulous weight, as illustrated in Exhibit Defendants' Transmitter, a distinctively novel feature of this instrument? And, if not, you may referr to any prior microphone transmitter which embodied it.

Ans. It is not. I find a device of this character described and figured in the United States patent No. 225,790, dated March 23, 1880, to Emil Berliner, of Boston.

Int. 32. Please compare Exhibit Defendants' Receiver with the receiving member L of the apparatus specifically described in the patent to Bell, No. 174,465, and shown in Fig. 7 of the drawings thereof, and state what differences in construction you find, and how such differences affect, if at all, the substantial likeness of the two instruments in respect to their function and mode of operation, and the work they do in the transmission of sound.

Ans. The operation of the Exhibit Defendants' Receiver is identical with the operation of the receiver shown in Fig. 7 of the patent to Bell, No. 174,465. In the defendants' magneto-receiver there is a permanent multipolar magnet having three legs. The polarity of the ends of the two outer legs is opposite to that of the middle leg. A coil of wire is wound about the poles of the multipolar magnet. This is substituted for the particular form of electro-magnet shown at *f* in Fig. 7, in which latter case the coil is wound about one pole of the electro-magnet only. Instead of the membrane and attached armature described by Mr. Bell, an iron diaphragm is used with its

centre opposite the pole at the end of the middle leg of the tri-polar magnet. The permanent magnet used in this instrument replaces the electro-magnet shown in the receiver L of the patent to Bell, No. 174,465, which does not affect the substantial likenss of the two instruments, since the function of the battery shown in Fig. 7 is merely to keep the core of the electro-magnet magnetized.

The magnetism of the permanent magnet of the Exhibit Defendants' Receiver is substituted for the magnetization produced by the current in the Bell receiver of Fig. 7. The metallic diaphragm of the Exhibit Defendants' Receiver replaces the combined armature and membrane diaphragm of the receiver shown in Fig. 7 of the patent to Bell, No. 174,465. In the Exhibit Defendants' Receiver, by means of a soft iron plate the periphery of the soft iron diaphragm is put in magnetic contact with the two outer poles of the permanent three-legged magnet, so that the centre of the disk has a polarity opposite to that of the end of the three-legged magnet which faces it. In like manner one leg of the electro-magnet, *f*, in Fig. 7 of the patent, No. 174,465, is so connected at *k* with the soft iron armature, *h*, that that portion of the armature, *h*, which is opposite the pole of the electro-magnet, *f*, has a polarity opposite to that of the pole of the electro-magnet, *f*, which it faces. None of the specific differences which exist between the Exhibit Defendants' Receiver and the receiver shown in Fig. 7 of the patent to Bell, No. 174,465, affects in any way the substantial likeness between them, either in respect to their function or mode of operation, or the work they do in the transmission of sound.

Int. 33. Among the patents to Henry Clay mentioned in the answer of the defendant, the Clay Commercial Telephone Company, under which it is averred that the telephones made, used and sold by it have been constructed, is No. 277,112, dated May 8, 1883, for Improvement in Telephones. Have you examined this patent, and do you understand the construction and mode of operation of the instrument therein described and shown; if so, will you compare it with the Exhibit Defendants' Receiver, and point out such substantial likeness or differences as you may find between the two, and state how you find the mode of operation of the instrument described in the patent, to compare with that of the apparatus described in the

patent to Bell, No. 174,465, in connection with Fig. 7 of the drawings thereof?

Ans. I have examined the patent referred to, and understand the construction and mode of operation of the instrument therein described. The Exhibit Defendants' Receiver is constructed in most respects in substantial conformity with the description given in the patent to Clay, No. 277,112. The chief difference which I notice between the two is in the manner of winding the coil about the ends of the three legs of the magnet.

In the exhibit the coil is so wound that it completely and separately encircles each of the three poles in such a manner that, looked at from in front, the direction in which at any moment the current circulates around the two outside poles is opposite to the direction in which it circulates around the middle pole. With this mode of winding, the effect of the current tends to augment or diminish the strength of all of the poles simultaneously, which is of course desirable in the operation of the instrument. In the instrument of the patent, the mode of winding is such that the wire is wound so that the current, at any moment, circulates in the same direction about all three poles; the wire surrounding the three poles collectively but not individually. With such a mode of winding the effect of the current is to augment the strength of the outer poles at the same moment that it diminishes the strength of the middle one, or conversely, an action which is evidently undesirable. Although this mode of winding tends to impair the efficiency of the instrument of the patent to Clay as compared with the Exhibit Defendants' Receiver, it in no way affects the identity of the mode of operation of the two instruments, in so far as they are both electric speaking telephones.

The operation of both the Exhibit Defendants' Receiver and the instrument described in the patent to Clay, No. 277,112, is substantially identical with the operation of the receiver, shown at L, in Fig. 7, of the patent to Bell, No. 174,465. This substantial identity of operation is recognized in the patent to Clay, No. 277,112, from the specification of which I quote the following: —

"The instrument is shown as a receiver, and the action of the current coming from the connected instrument over the wires, which enter or are secured to the posts G, is continued through the coil

G around the entire magnetic field, and as the current varies, the magnetism in the magnet also varies and exerts its action on the diaphragm F, causing the same to vibrate, and thus to emit sounds corresponding to those received by the instrument at the other end of the line."

[*Counsel for complainants puts in evidence the patent to Henry Clay just referred to, and the same is marked "Exhibit Clay Patent No. 277,112, Chas. H. Swan, Special Examiner."*]

Int. 34. Will you refer to the second Bell patent, No. 186,787, which has been produced in evidence, and describe briefly so much of the apparatus therein described as is referred to in the third, fifth, sixth, seventh and eighth claims; pointing out the functions or results which are attributed to the parts of the apparatus referred to in those claims?

Ans. Claim 3 is as follows: —

"3. The combination, with an electro-magnet, of a plate of iron or steel, or other material capable of inductive action, which can be thrown into vibration by the movement of surrounding air or by the attraction of a magnet."

By this I understand an electro-magnet combined with a plate of iron, steel or other material capable of inductive action.

To satisfy the conditions of this claim the plate must be of such material, size, thickness and elasticity, and must be so mounted and arranged with reference to the magnet, that on the one hand the delicate air vibrations characterizing articulate speech may be able to impart their vibration to it without substantial alteration in character; while on the other hand it is capable of being set into vibration through the action upon it of the minute changes imparted to the magnet by the variations in the current passing through the coil surrounding it, when those variations are of the delicate character which are employed in the transmission of speech in the speaking telephone.

Claim 5 is as follows: —

"5. The formation, in an electric telephone such as herein shown and described, of a magnet with a coil upon the end or ends of the magnet nearest the plate."

This claim relates to the special form of magnet suited for use in an electric telephone, the coil being placed about the end or ends of the magnet nearest the plate. The object of thus placing the coil is to render the magnet quicker in its working; that is, more ready to respond with the requisite rapidity to the variations in the strength of the current passing through the coil. A magnet with the coil thus placed responds more quickly by changes in its strength to slight changes in the strength of the current, and hence it is better adapted for use in the speaking telephone than a magnet in which the coil surrounds the whole length of the magnet, and which consequently acts more slowly.

Claim 6 is as follows: —

"6. The combination, with an electric telephone such as described, of a sounding-box, substantially as herein shown and set forth."

In this claim is mentioned the sounding box, which is combined with the telephone. This sounding box has an important influence in screening the plate of the instrument from the effect of extraneous sounds. The thin air space in front of the plate also exercises an important influence.

Claim 7 is as follows: —

"7. In combination with an electric telephone, as herein described, the employment of a speaking or hearing tube for conveying sounds to or from the telephone, substantially as set forth."

The speaking or hearing tube mentioned in this claim serves to concentrate the sounds produced by the voice upon the diaphragm when used as a transmitter, or to convey to the ear the sounds produced by the diaphragm when used as a receiver.

Claim 8 is as follows: —

"8. In a system of electric telephony, the combination of a permanent magnet with a plate of iron or steel, or other material capable of inductive action, with coils upon the end or ends of said magnet nearest the plate, substantially as set forth."

In this claim I find mentioned the combination of a permanent magnet with coils upon its end or ends, as described, with a plate of iron or other material capable of inductive action. The use of the

plate of iron, in connection with the magnet, as described, in a system of electric telephony, furnishes a most excellent method of causing the electrical and magnetic variations of the apparatus to produce corresponding vibrations in the air.

Int. 35. Referring to the defendants' instruments, which have been introduced in evidence, will you compare them with the apparatus described in the patent last referred to, and state how far, if at all, you find them to embrace the features or combinations described in that patent, and referred to in the claims above specified?

Ans. In the Exhibit Defendants' Receiver I find a magnet combined with a plate in the manner described in claim 3. I also find that this magnet has a coil upon the ends which are nearest the plate as described in claim 5; these ends being the terminations of the several legs of the three-legged magnet of the Exhibit Defendants' Receiver. I find also a permanent magnet as described in claim 8. The magnet in Exhibit Defendants' Receiver and the microphone in Exhibit Defendants' Transmitter are placed within a sounding box as described in claim 6. Both Exhibit Defendants' Transmitter and Exhibit Defendants' Receiver possess the speaking and hearing tube mentioned in claim 7. In the Exhibit Defendants' Receiver the hearing or speaking tube is so arranged as to leave a thin space filled with air in front of the vibrating plate.

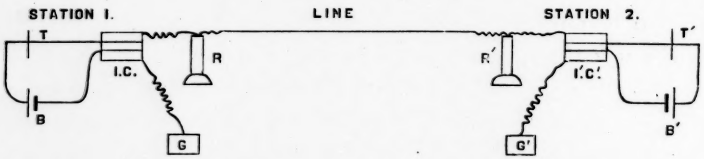
Int. 36. I find in the second Bell patent a statement that the same instrument is used both as transmitter and receiver, and I understand that the electrical and magnetic portions of the apparatus described in Bell's first patent are the same both in the transmitter and receiver, the instruments differing merely in the forms of the cones, one of which is especially adapted to enclose the mouth, while the other is shaped so as to enter or be applied to the ear; will you state whether the magneto-telephone Exhibit Defendants' Receiver is, when properly connected in line with another instrument of the same kind, capable of being used as a transmitter as well as a receiver?

Ans. It is capable of being used both as transmitter and receiver under the circumstances mentioned.

Int. 37. Will you describe the character of the circuits and connections indicated by the structure of the defendants' two instru-

ments, and usual with a speaking telephone apparatus which includes a battery transmitter, and then state whether the magneto-instruments, as arranged at the two ends of the line, will be so connected in circuit with each other that, without any change, speech uttered into one will be heard at the other?

Ans. I make the following drawing to illustrate my meaning: —



In the figure, I C and I′ C′ are two induction coils; B and B′ are voltaic batteries, and T and T′ transmitters in the primary circuits of the coils. R and R′ are magneto-telephones placed in a line connected with one terminal of the secondary wire of each induction coil. G and G′ are earth plates, with connecting wires running to the other terminals of the secondary wires of the induction coils. G and G′ are buried in the earth, so that the secondary circuit is completed through the earth, and includes the secondary helices of the two induction coils, and the two magneto-telephones R and R′. Speech actuating either T or T′ is reproduced in the receivers R and R′. Also, if either R or R′ be spoken into and used as a transmitter, since R and R′ are joined in complete circuit by means of the line wire, the secondary wires of the coils, and the earth, speech will be reproduced in the other receiver, as when the apparatus shown in Fig. 7 of the first Bell patent, or Figs. 4 and 6 of the second Bell patent, is used.

This is the ordinary arrangement, and, as indicated by the construction of the defendants' transmitter, is the arrangement intended to be used by them. Indeed, it is not uncommon on ordinary telephone lines, as thus arranged, to use one of the magneto-instruments as a transmitter, when for any cause the microphone transmitter, the battery, or any portion of the primary circuit is out of order.

Int. 38. I understand from your previous testimony that in a speaking telephone apparatus consisting of transmitters, receivers, batteries and other adjuncts, as shown in the above diagram, the

articulate speech uttered into any transmitter is heard at the receiver as the same articulate speech in consequence of the electrical undulations similar in form to the sound waves, and that those electrical undulations are caused by the utterances of the speaker which said sound waves are due to or accompany. I wish you would now state, by reference to said diagram, in what part of the whole apparatus, including in that phrase the various circuits, those electrical undulations exist, and in what part they must exist and be operative in order that speech may be transmitted so as to be intelligible to the listener.

Ans. If a person speaks into one of the transmitters, as, for example, T at station 1, the current produced in the primary circuit by the battery B is thrown into the described electrical undulations by the action of the voice upon the transmitter. These undulations occur throughout the whole primary circuit of the induction coil I C. Similar electrical undulations are produced in the secondary of I C, and in the whole circuit of which it forms a part, including the magneto-telephones R and R′, and the secondary wire of the induction coil I′ C′. Similar undulations are also produced in the primary of the induction coil I′ C′; but in this circuit they have no importance. These electrical undulations are produced in the primary circuit by the action of the voice upon the transmitter. It follows, from the relation of the primary and secondary helices of the induction coil, that undulations similar in form are produced in the secondary wire, the line, and the receiving instruments placed in the circuit. It is because of the presence of these electrical undulations in the secondary circuit, and of their similarity to the undulations produced by the voice in the primary circuit, that words spoken into the transmitter are reproduced by the receiver.

[*Adjourned.*]

BOSTON, Dec. 18, 1884.

Int. 39. Since the conclusion of your direct examination, November 22, 1884, a decision has been rendered for the complainants in the suit of the American Bell Telephone Company *et al. v.* The People's

Telephone Company *et al.*, in the United States Circuit Court for the Southern District of New York. Did you testify as an expert in that case, and were you familiar with the telephonic apparatus therein complained of, and now held by the Court to infringe upon the aforesaid patents to Bell? If so, what was the character of the transmitting instrument to which the decision in that case applied?

Ans. I did testify in that case, and was familiar with the transmitting and receiving instruments which were employed. The transmitter was a microphone transmitter, embodying the same mode of operation as that found in the Blake transmitter and other microphones.

Cross Examination by FURMAN SHEPPARD, Esq., *of Counsel for Defendants.*

Cross-Int. 40. Have you ever been practically engaged in telephony as a business or an occupation; and, if so, when, where, in what capacity and for how long?

Ans. I have never been engaged in telephony either as a business or as an occupation.

Cross-Int. 41. What was the state of the art as to the electrical transmission of sound, prior to the alleged invention or discovery described and claimed by Bell in his patent of 1876, No. 174,465?

Ans. The principal published papers upon the subject were those of Reis, whose circuit-breaking transmitter was well known, both in this country and abroad, long before the date of Mr. Bell's invention. There were also various notices of the apparatus of Reis in different scientific and other publications. Reis had attempted to transmit speech, but so far as appears to me from his original papers, without practical success. There were a few other papers containing descriptions of suggestions or apparatus of Bourseul, Van der Weyde, and others, but in none of these papers, so far as I am aware, is there any indication that articulate speech was transmitted. The only forms of instruments which I know of as having been described before 1876 were different forms of circuit-breaking transmitters. These instruments transmitted the pitch of different musical sounds, including the pitch of the voice, with success.

Cross-Int. 42. In the state of the art prior to the Bell patent of 1876, what is the nearest approach you find to the thing claimed in the fifth claim of that patent, and to the devices represented in Fig. 5 and Fig. 7 of said patent?

Ans. I do not know of anything more closely approaching the device of Fig. 5 than some of the circuit-breaking multiple telegraph transmitters of Gray and Bell. I do not think of anything approaching Fig. 7 more closely than the Reis transmitter. There is an old suggestion by Bourseul regarding the use of vibrating plates, one at each of two stations, but he does not describe any apparatus. The circuit-breaking instruments, to which I have referred, differ from the apparatus of Figs. 5 and 7 in the fact that they in no way endeavor to preserve substantial continuity in the electrical current. The fifth claim appears to me to embody an entirely original idea, which I do not find in earlier publications.

Cross-Int. 43. What are the principal theories that have been from time to time propounded respecting the nature of electricity, and the nature and cause of electrical action; and in what theory, if in any, are the leading electricians of the present day agreed?

Ans. It would of course be impossible for me to give, in any answer of reasonable brevity, a clear reply to the question which I am asked. We find that when two dissimilar bodies are rubbed together, they in general assume a condition in virtue of which they are capable of attracting each other. Each will also attract conducting bodies which have been placed in contact with the other, and repel conducting bodies which have been placed in contact with itself. We express this difference of state by saying that the bodies originally rubbed together are oppositely electrified, or oppositely charged, or that they are at different electrical potentials. Conventionally we may speak of one of these bodies as electrified positively, and of the other as electrified negatively; these terms being mere conventions, and not necessarily implying the truth of any particular theory. If we connect one of these bodies with the other by a wire, we find that this wire acquires temporarily certain properties which

it does not possess under ordinary circumstances. It will attract a piece of iron, or if it is coiled around an iron bar will render the bar magnetic. It will also deflect a compass needle from a north and south line, if the wire is held parallel to the needle. The same effects will occur if either of the charged bodies is connected by means of the wire to the earth, or to an unelectrified body; and we find that the charge of the electrified body under these circumstances rapidly diminishes until it is reduced to zero. It is evident from this, together with other facts, that some change is propagated along the wire, and in order to avoid circumlocution we imagine something which we call "electricity" to pass from the charged body through the wire, and speak of these actions, which I have mentioned, as due to what we call "the electric current."

We assume conventionally that the current flows from the positively to the negatively electrified body, from the positively electrified body to the earth, and from the earth to the negatively electrified body. We speak of the "potential" or electrical level of the positively electrified body as being higher than that of the earth, and of the potential of the negatively electrified body as being lower than that of the earth, assuming the earth to be at a potential or electrical level of zero; measuring our electrical level as above and below the electrical level of the earth, something as we measure an elevation or depression on the earth's surface as above or below the level of the sea.

It is very probable that there is something to which we give the name electricity which actually passes through the conducting wire among its molecules. It has been supposed by Edlund that the electrical current might be a current of the luminiferous ether, that medium which we suppose to fill all space, and by means of waves in which light and heat are transmitted to us from the sun.

When a body is electrified it brings the medium in which it is placed, if this be a poor conductor, into a condition which may be called "electrical strain," this being analogous to the mechanical strain which is set up in ordinary matter under the action of a distorting force. This state of strain can be brought about and kept up only in *media* which will not allow the electricity readily to pass

through them from particle to particle. From the observed effects of currents flowing in a wire upon magnets, and of magnets upon currents, we are led to infer the existence of vortical motions in the ether which surrounds all bodies. The phenomena of attraction and repulsion of charged bodies, and of the reciprocal actions between magnets and currents of electricity have been explained by Maxwell as the result of tensions and compressions existing in small rotating masses of the ether. We have the strongest reason for believing that it is the same ether through which are propagated both light waves and the electrical disturbances which act through non-conducting *media*, and also for supposing that light itself is an electro-magnetic disturbance in the ether. Maxwell has shown that the various known electrical phenomena can be accounted for by supposing the existence of a pull along certain definite lines known as "lines of magnetic force," and a thrust in a direction at right angles to these; and he accounts for the existence of this pull and thrust, by forces called into play from the vortical or rotary motions of small particles or cells of the insulating medium through which electrical disturbances are propagated. When a current passes through a wire, these vortices are produced in the space about the wire.

I have spoken of the production of a current of electricity by connecting a charged body with the earth. Such a current is very brief, owing to the fact that as the charged body contains only a limited quantity of what we call electricity, it is speedily discharged by the passage of the electricity as an electrical current through the wire to the earth. We can, however, produce a continuous current by the use of a voltaic battery, and the properties of this current are identical with the properties exerted by the transient current so long as the latter exists. I think that scientific men generally are inclined to accept provisionally at least the views which I have stated as explaining electrical phenomena.

Historically a good many different theories have been held. Franklin supposed that when two bodies are rubbed together one of them loses a portion of a normal charge of electricity which all bodies have, while the other gains an equal amount. The former

body he calls *negatively*, the latter *positively*, electrified. Symmer and Dufaye imagine the existence of two opposite electricities which they call *vitreous* and *resinous* electricities, but which have since generally been called positive and negative electricities: these two kinds of electricity attracting each other, and when combined together in equal quantities neutralizing each other as an acid neutralizes an alkali. In unelectrified bodies these electricities exist in equal quantities, and neutralize each other; but when two bodies are rubbed together, the positive electricity passes to one, and the negative electricity to the other. The terms "positive" and "negative" electricity are still in common use among scientific men, but in a purely conventional sense, as I suppose no one competent to form an opinion accepts this theory. In discussing the phenomena of the voltaic battery, this theory supposes a current of positive electricity to flow through the circuit from the copper pole of the battery, and an opposing current of negative electricity to flow in the opposite direction from the zinc pole; but it has not been customary to consider any but the positive current, and the language of the single fluid theory of electricity has generally been used in describing the phenomena of the electrical current.

Cross-Int. 44. What is the theory of the nature of electricity, and of the nature and cause of electrical action that is accepted or adopted by you?

Ans. The theory which I have explained most at length in my last answer as being generally adopted by scientific men, I should accept as a working hypothesis. I prefer, however, in discussing electrical phenomena to avoid the assumption of any particular theory as to the nature of electricity. Its laws of action are perfectly well known, and a knowledge of these is of far more practical importance than the discussion of any particular theory.

Cross-Int. 45. What do you understand by the expression "current of electricity," or by the word "current," as applied to electricity?

Ans. When I speak of a current of electricity as flowing through a wire, I mean it to be understood that the wire, in consequence of the electrical state in which it has been placed, exhibits various electrical and magnetic phenomena which under ordinary conditions

it does not manifest. The condition assumed by the wire is capable of propagation from one point of the wire to another. We also find that we can increase or diminish the effects produced in virtue of the electrical condition of the wire, diminishing the magnitude of these effects when we increase the length of the wire or when we decrease the section of the wire, and increasing them by making the opposite changes in the length and section. We can also produce periodical changes in the condition of the wire, and hence in the magnitude of its electrical or magnetic effect. These facts immediately suggest to the mind an analogy between the electrical changes and the changes which may take place in a tube conveying a current of water. By increasing the length of such a tube the velocity of the current, and hence what we might call the strength of the current, as measured by the quantity of water passing a given section of the tube in a second, is diminished. By increasing the diameter of the tube the flow is increased. If we increase the head or pressure upon the water, the flow is also increased, and in like manner by increasing the difference of potential or electro-motive force between two ends of a wire we may proportionally increase the magnitude of the electrical phenomena manifested by the wire. We therefore analogically refer the production of the electrical phenomena, which I have mentioned, to the action of an electrical current which we imagine to flow through the wire, which current, like the current of water in the pipe, encounters a certain resistance to its passage, this resistance being increased when the length of the wire is increased, and diminished when the section of the wire is increased, so that the strength of the electrical current will thus be varied. Variations, whether slow or rapid, periodic or otherwise, in the magnitude of the electrical and magnetic phenomena manifested by the wire, we ascribe to similar variations in the electrical current. We do not necessarily assume the truth of any particular theory in using these terms, but they are employed because of the well-known analogy which I have mentioned, and they are universally used and understood by those conversant with electrical science. It is very probable, however, that there actually is a flow of something, to which we give the name "electricity," through the wire.

Cross-Int. 46. Describe the motion, if motion it be, that constitutes a current of electricity, and state what it is that moves.

Ans. Not knowing certainly whether there is an actual propagation of something through the wire, I can answer the question only by assuming the truth of some hypothesis. It is quite probable that in a conductor, particles of something quite distinct from ordinary solids, liquids or gases passes along the wire. To this we give the name "electricity." We are entirely ignorant of its nature, but at the same time are capable of measuring it quantitatively by its effects, so that, following out our analogy, we can assert that under different circumstances of resistance and electro-motive force, different definite quantities will pass a given section of the circuit in a second.

We can ascertain as exactly the relation between these quantities as we can ascertain the relative weights of different masses of matter. We can measure the capacity which bodies have for holding electricity. We can predict exactly how much heat will be produced in a wire when a definite quantity of electricity passes through it. We can predict precisely what weight of water or other chemical compound will be decomposed into its elements, when a given quantity of electricity passes through it. We can calculate exactly what quantity of electricity will be produced when a definite amount of zinc is consumed in the cell of a voltaic battery. Nevertheless, we do not know what the mode of motion in the electrical current is, nor the nature of the material which moves.

Cross-Int. 47. State whether or not that motion is a motion of translation, or, in other words, a motion which involves change from place to place?

Ans. There is apparently a translation of something from place to place, but we know nothing whatever about the velocity with which the electrical current travels. It may be very great or very small, we have no means of knowing which. All our measurements of the velocity of electricity, so called, merely determine the velocity with which any change in the electrical current, as, for instance, an undulation produced in it, is propagated.

Cross-Int. 48. What do you understand by the word "intermittent" as applied to a current of electricity?

Ans. I understand an intermittent current to be a discontinuous current. Such a current, for example, as is produced on making and breaking the circuit of a battery by alternately placing the circuit wires in contact and separating them.

Cross-Int. 49. What do you understand by the word "pulsatory," as applied to a current of electricity?

Ans. The term "pulsatory" has not been as generally employed in electricity as the term "intermittent." I understand by it, however, a current which sustains sudden variations in its strength, with intervals of constancy between them, such as would be produced, for example, upon a wire through which a constant current from a battery was flowing, if we were to superpose upon it a current from another battery, which latter current was frequently made and broken. This would give rise to sudden variations in the total strength of the current flowing in the wire, but this current would never fall to zero; merely rising suddenly from its normal strength to a maximum, and then falling again.

Cross-Int. 50. What do you understand by the word "vibratory," as applied to a current of electricity?

Ans. The term "vibratory current" has not been in common use, and it is not one which I should preferably make use of, because it might easily be misunderstood. I should understand by the term, however, that the current in the circuit sustained periodic variations in strength and perhaps in direction also, which might be spoken of as "vibrations." I think that the term "undulatory current," which expresses the same idea, is preferable to the term "vibratory current." In using the term "periodic variations," I intended to imply that there was a more or less gradual change in the strength of the electrical current.

Cross-Int. 51. What do you understand by the word "undulatory" as applied to a current of electricity, and what is the fact or the analogy, or what is it otherwise that has led to the application of that word to a current of electricity?

Ans. By an undulatory electrical current I understand a current which sustains periodic variations in strength, or in both strength and direction; these variations being continuous in their nature, so

that if we were to employ a graphical method of representing the strength of an electrical current, a wavy or undulating curve would represent the strength of the electrical current at any point of the circuit at successive instants. I suppose that it was the wavy character of the curve representing the strength of the current that led to the use of the term "undulatory," or it may have been suggested by the fact that the periodic electrical variations occurring are expressed by the same formulæ that express the motions of air particles in a sound wave.

Cross-Int. 52. What do you understand by the word "oscillation," as applied to a current of electricity?

Ans. Such a periodic variation in the current as I have described in my last answer constitutes an electrical oscillation.

Cross-Int. 53. Do you consider the three words "oscillation," "vibration" and "undulation" as synonymous in meaning?

Ans. The terms "vibration" and "oscillation" I should understand as being synonymous in all cases. In electricity I should understand the terms "vibratory current," "undulatory current" and "oscillatory current" to be synonymous. In physics we generally apply the term "oscillation" or "vibration" to the motions of the separate particles composing a wave, and the term "undulation" to the wave as a whole.

Cross-Int. 54. Do you consider the two words "intermittent" and "pulsatory" as synonymous in meaning?

Ans. I do not.

Cross-Int. 55. Which, if any, of these five designated currents, viz., intermittent, pulsatory, vibratory, undulatory and oscillatory, do you find in the previous state of the art to accompany, or to be concerned in, the electrical transmission of sound?

Ans. The intermittent current only.

Cross-Int. 56. What do you understand to be the difference, if any there is, between the meaning of the expression "undulatory currents of electricity," in the first claim of the patent of 1876, No. 174,465; the expression, "electrical undulations," in the second claim; the expression, "undulations in a continuous voltaic current," in the third and fourth claims; and the expression, "electrical undulations," in the fifth claim?

[*Objected to as inadmissible and incompetent, because calling for*

the interpretation of a written instrument which it is the peculiar province of the Court to construe; and further, because — as to the first, second, third and fourth claims — not opened in the direct examination.]

Ans. I understand the electrical variations referred to in each of the claims mentioned to be of the nature which I have already described in my answer to Cross-Int. 51, as characterizing electrical undulations.

Cross-Int. 57. Define what is meant by a continuous current of electricity, and state what are the distinguishing or distinctive characteristics of such a current.

Ans. By a continuous current we understand a constantly flowing current in which there are no interruptions. The one distinguishing characteristic of such a current, in strictness, is that it flows continuously.

Cross-Int. 58. What are the specific differences, if any there be, between the nature and characteristics of a continuous current of electricity, and of a discontinuous current?

Ans. A continuous current flows continually, and although its strength may vary, the current does not cease. A discontinuous current is one in which there are breaks or gaps of continuity. In making these statements I am stating broadly the general sense in which these terms would be understood.

Cross-Int. 59. How far, if at all, and to what extent, does the fact that a current of electricity is in one case continuous, and that in another case it is discontinuous, affect the character or nature of the current itself?

Ans. The current itself, while it lasts, is of the same nature in the two cases; that is, during that portion of the time in which the intermittent current is actually flowing, during the period between the breaks, the current is of substantially the same nature as it would be if continuous.

Cross-Int. 60. Is the expression "continuous current of electricity" used in contradistinction to what is commonly called "a make-and-break current"; and, if so, define precisely and particularly what is meant by a make-and-break current; and state what it is that constitutes, in your opinion, a make-and-break current, and

what are the *criteria* by which a continuous current may be in all cases absolutely contradistinguished from a make-and-break current?

Ans. The expression "continuous current" is ordinarily used in contradistinction to the expression "discontinuous current." By the term "make-and-break current," when used, I should understand a current in which there were sudden interruptions, causing complete gaps in the continuity of the current. Strictly speaking, these gaps would have to last for a finite interval of time. I think that the characteristics of the two classes of current mentioned are absolute and necessary, and constitute the *criteria* by which we distinguish the one from the other.

[*Adjourned.*]

DEC. 19.

Cross-Int. 61. Is the form of the electrical undulations, which transmit or reproduce articulate speech, different from the form of the undulations which transmit or reproduce non-articulate vocal utterance?

Ans. It is. For every different quality of sound there is a different and characteristic electrical undulation.

Cross-Int. 62. Is or is not the form of the wave of a continuous undulatory electrical current different from the form of the wave of a discontinuous undulatory current?

Ans. If I understand the question correctly, I am asked, substantially, whether the form of a continuous undulatory current (as I have defined an undulatory current) would be altered by simply omitting small portions of that current, without producing any other changes whatever, so that the continuous undulatory current would be graphically represented by a continuous curved line, whereas the discontinuous undulatory current would be represented by a dotted curve or by a curve composed of small curved lines, and exactly similar to the continuous curve, except that certain small portions are omitted. It seems to me, reasoning from the laws of acoustic vibrations, that the nature of the curve, and hence the nature of the undulation, would not necessarily be changed by the mere omission of certain small portions. The character of the curve is determined by what remains, provided of course that there is a sufficient amount remaining to specifically determine its nature. Of

course if the character of the curve representing the undulation is the same the form is substantially the same.

Cross-Int. 63. Do the devices represented in Fig. 5 and Fig. 7 in the patent of 1876, No. 174,465, transmit and reproduce musical sound, both vocal and instrumental?

Ans. The device represented in Fig. 7 will transmit and reproduce both vocal and instrumental musical sounds. The device represented in Fig. 5 is adapted only to transmit and reproduce a certain definite and limited number of vibrations; that is, those vibrations which can be executed by the steel spring armatures *c* and *h*. The device shown in Fig. 5 is especially adapted only to transmit such vibrations as would be produced by setting the spring *c* into vibration in some manner; as, for example, by plucking it with the finger, or by means of a current of air. These vibrations will in general be musical in their nature, and it will therefore transmit the corresponding particular musical sound. In this sense the device will transmit certain instrumental musical sounds. It is not adapted, however, to transmit either instrumental or vocal sounds produced in the air about it, and hence, speaking broadly, cannot serve as a transmitter of vocal and instrumental musical sounds in general.

Cross-Int. 64. Why is it that the device represented in Fig. 5 is not adapted to transmit either instrumental or vocal sounds produced from the air about it?

Ans. Because, as is well known to those familiar with the principles of acoustics, such a tuned reed can vibrate in only a limited number of ways, and hence can transmit only a correspondingly limited number of sounds. Furthermore, it is not particularly well adapted to take up vibrations from the air about it. This last statement will perhaps be clearer if we compare a stretched membrane with the steel spring armature. The stretched membrane is light, elastic, and offers a large surface upon which the air waves can fall. It can, moreover, vibrate in an exceedingly great number of different ways. The steel spring armature is heavier, offers less surface to the air, and because of its mass, dimensions, and mode of attach-

ment, can vibrate much less readily and in a comparatively small number of ways.

[*Note.* — *A recess was taken at this point, and after the recess Chauncey Smith, Esq., attended as counsel for complainants, Mr. Roberts having been called away to keep a previous engagement.*]

Cross-Int. 65. Do the graphic forms of curves which represent articulate speech differ from the forms of those which represent non-articulate speech; and if so, in what respects or characteristics do they differ?

Ans. The graphic forms of curves which represent articulate speech do not, speaking generally, differ in their nature from those representing non-articulate vocal sounds. Each particular vocal sound, whether articulate or inarticulate, is represented by a corresponding curve.

Cross-Int. 66. Do the graphic forms of curves which represent articulate speech differ from the forms of those which represent musical sounds; and if so, in what respect or characteristics do they differ?

Ans. They do not differ in their nature.

Cross-Int. 67. In speaking of the subject matter of the patent of 1876, No. 174,465, you have used the word "articulate." Why have you used that word in connection with that patent?

Ans. I suppose that the question refers to my use of these expressions in my answer to Int. 7, on p. 119 of the printed record; I have there used the term "articulate speech" because it is with the transmission of articulate speech that the speaking telephone is especially concerned.

Cross-Int. 68. What do you understand to be the meaning of the expression "articulate speech" in that connection?

Ans. I understand it to mean distinct words or sentences; that is, such a peculiar succession or combination of sounds as we use by common consent to express particular ideas; such a combination of vowel and consonant sounds as we habitually use in speaking, as distinct from the sounds of crying or singing without the use of definite words.

Cross-Int. 69. How often, if at all, has the patentee used the word "articulate" or the expression "articulate speech" in the specifica-

tion of the patent of 1876, No. 174,465, in defining its subject matter?

Ans. I do not recollect that the words "articulate speech" are used in the patent.

Cross-Int. 70. In the expression "vocal or other sounds," as used in the fifth claim of the patent of 1876, No. 174,465, what do you understand by the words "vocal sounds"?

Ans. Any sounds produced by the vocal organs..

Cross-Int. 71. In human beings what is the organ of vocal sounds?

Ans. The various portions of the throat and mouth cavity.

Cross-Int. 72. Can you state in what sense physiologists use the expression "vocal sounds"?

Ans. My understanding of the use of the term "vocal sounds" is that which I have given above. I was not aware that physiologists used the term in any special or more limited sense.

Cross-Int. 73. What is the difference, if any there be, as you understand it, between vocal sounds and articulate speech.

Ans. The term "vocal sounds" is broader and includes articulate speech. All articulate speech is composed of vocal sounds, but there are vocal sounds which are not articulate.

Cross-Int. 74. In human beings what is the organ of articulate speech?

Ans. The various organs of the throat and mouth, especially the mouth cavity, the lips, the tongue and the teeth.

Cross-Int. 75. Can you state in what sense physiologists use the expression "articulate speech"?

Ans. So far as I know, they use it in the sense which I have already attributed to the expression.

Cross-Int. 76. Can you state in what sense, if in any, physiologists distinguish between vocal sounds and articulate speech?

Ans. So far as I am aware a physiologist would use both of these terms in the senses which I have already attributed to them.

Cross-Int. 77. In the expression "vocal or other sounds" as used in the fifth claim of the patent of 1876, No. 174,465, what do you understand to be included in the words "other sounds"?

Ans. Any sounds which are not produced by the voice.

Cross-Int. 78. Do you understand the expression "vocal or other sounds" to include musical sounds and also noises?

Ans. I do.

Cross-Int. 79. In your testimony in chief you speak of "the well-known Reis instrument" and "the action of the Reis apparatus"; state specifically to what published description or representation of that instrument or apparatus you refer in thus speaking of it.

Ans. I did not have any one particular description of the Reis apparatus in mind, in what I said. Very good descriptions of the Reis apparatus, however, are found in the following well-known works: "Die Neuren Apparate der Akustik," by Pisko, published in Vienna in 1865, p. 94; Kuhn's "Handbuch der Angewandte Elektricitätslehre," published in Leipsic, in 1865, p. 1017; and Hessler's "Technical Physics," published in Vienna, 1866, Vol. I., p. 648. There are also very full descriptions by Reis and Legat in the yearly report of the Physical Society at Frankfort, published in 1862, and in the journal of the German-Austrian Telegraph Association for 1862.

Cross-Int. 80. You say in your testimony in chief that "the apparatus of Reis was intended to produce mere intermittences, the frequency of which corresponds to the pitch of the sound produced." Please state the source of your knowledge as to what the instrument was "intended" to produce.

Ans. My knowledge of the Reis instrument and of the mode in which its inventor intended it to operate is derived from the papers to which I have referred, together with various other papers on the same subject.

Cross-Int. 81. Please specify those other papers.

Ans. The following are the principal ones: *Frankfurter Conversationsblatt*, Nov. 29th, 1861; *Fortschritte der Physik*, XVII., for 1861, pp. 171–3; *Deutsche Industrie Zeitung*, 1863, Chemnitz, April 17, 1863, No. 16, p. 184; May 1, 1863, No. 18, p. 208; May 29, 1863, No. 22, p. 249; *Böttger's Polytechnisches Notizblatt*, 1863, No. 61; Reis's Letter to Ladd, *Journal of the Telegraph Engineers and of Electricians* for March, 1883, No. 46; *The Newcastle Daily Chronicle and Northern Counties Advertiser*, Saturday, Aug. 29, 1863; Report of the Thirty-third Meeting of the British

Association for the Advancement of Science, in August and September, 1863, published 1864; Prospectus of Mr. Albert, August, 1863; Circular of Reis; Reis's Descriptive Circular; *Dingler's Polytechnic Journal*, Vol. CLXIX., p. 169; *Fortschritte der Physik*, 1863, p. 96; *Gartenlaube*, No. 51, December, 1863; *Cosmos*, Vol. XXIV., pp. 349, 352, printed and published at Paris, March 22, 1864; Proceedings of the Literary and Philosophical Society of Manchester, published at Manchester, 1865; Koenig's *Catalogue des Appareils d'Acoustique*, Paris, 1865, p. 5; Pisko's *Neuren Apparate der Akustik*, Wien, 1865, p. 241; Catalogue of J. W. Albert, mechanician, at Frankfort-on-the-Main, 1866; *Electricity*, by R. M. Ferguson, London, 1867, p. 257; *Lehrbuch der Physik und Meteorologie, von Joh. Müller, Siebente Auflage, Zweiter Band*, 1868, pp. 386–389; *The Manufacturer and Builder*, May, 1869, Dr. Van der Weyde's article, The Telephone; *The Wonders of Electricity*, translated from the French of J. Baile, New York: Scribner, Armstrong & Co. 1872, pp. 140–143; Catalogue of J. W. Albert, mechanician, at Frankfort-on-the-Main, 18[illegible]3; Dr. Van der Weyde's second article, The Invention of the Telephone, *Scientific American*, March 4, 1876; Report of the Exhibition of Scientific Apparatuses in South Kensington Museum, London, 1876, p. 188, Group 6, Sound, 922; Report of the Forty-seventh Meeting of the British Association for the Advancement of Science, held at Plymouth, in August, 1871, article by W. H. Preece, On the Telephone; *The Telephone*, by Prof. A. E. Dolbear, Boston, Lee & Shepard, 1877, pp. 99–116.

[*Adjourned.*]

DEC. 20, 1884.

Cross-Int. 82. Referring to the drawings attached to the patent of 1876, No. 174,465, state what difference, if any, there is, in principle and mode of operation between the device represented by Fig. 5 and that represented by Fig. 6.

Ans. It seems to me that they both embody the same principle and mode of operation.

Cross-Int. 83. Please state the difference, if any there be, in principle and mode of operation, between the device represented by Fig. 6 and that represented by Fig 7, in said patent of 1876.

Ans. The instruments are similar in the fact that they both pro-

duce electrical undulations by the motion of an armature in front of the pole of an electro-magnet, and in the fact that these electrical undulations are similar in form to the vibrations of the armatures by which they are produced. In this respect they are similar in their principle and mode of operation. They differ in the fact that, as I have already explained, the apparatus of Fig. 7 is adapted to transmit vocal or other sounds in general, by producing electrical undulations similar in form to the air waves accompanying them; whereas the apparatus of Fig. 6 is adapted to transmit and reproduce only a very limited number of sounds corresponding to the periods of vibration of the steel springs. Acoustically there is then this dissimilarity between the two pieces of apparatus, that one, that represented in Fig. 7, is adapted to transmit sounds in general, whereas the other, that represented in Fig. 6, is adapted to transmit and reproduce only special and quite definite sounds.

Cross-Int. 84. Please state the difference, if any there be, in principle and mode of operation, between the device represented by Fig 5 and that represented by Fig. 7, in said patent of 1876.

Ans. In my opinion the differences between the apparatus shown in Fig. 5 and that shown in Fig. 7 are the same as the differences between the apparatus of Fig. 6 and that of Fig. 7; since the apparatus of Fig. 6 differs from that of Fig. 5 only in the fact that there are several spring armatures capable of vibrating in different periods, instead of a single spring armature; so that the former apparatus is capable of transmitting a greater number of sounds than the latter, though this number is limited by the number of spring armatures used.

Cross-Int. 85. What is the difference, if any there be, between the device represented in Fig. 6 and the devices represented in Fig. 5 and Fig. 7, in said patent of 1876, as respects the nature and character of the current which passes along the line wire?

Ans. The nature and character of the current is in both cases undulatory. The differences in the current in the different cases mentioned are analogous to and correspond to the differences which exist betwen the acoustic vibrations by which these electrical undulations are produced.

Cross-Int. 86. What is the relation or connection, if any there is, between the invention, if any there be, which is represented in Fig. 6, and the invention, if any there be, which is represented in Fig. 7, in said patent of 1876?

Ans. In both devices the receiver is set in vibration by the employment of electrical undulations.

Cross-Int. 87. Please refer to the question, and state if you have anything to add to the foregoing answer.

Ans. So far as I can see, in the light of my preceding answers, this statement shows the important relation which exists between the two devices, as it states an invention which is employed in both. There are, of course, other novel uses of electrical principles common to the two, as, for example, the use of a permanent magnet with a closed circuit, so that vibrations of an armature shall occasion electrical undulations in the circuit.

Cross-Int. 88. Which, if any, of the drawings attached to the said patent of 1876, is the one that, in your opinion, illustrates or embodies the fifth claim of said patent?

Ans. Fig. 7 is the one which especially illustrates the fifth claim.

Cross-Int. 89. What is the part or portion of the specification of the said patent of 1876 which, in your opinion, describes or points out the subject matter of the fifth claim of said patent?

Ans. The following portion: —

"One of the ways in which the armature *c*, Fig. 5, may be set in vibration has been stated above to be by wind. Another mode is shown in Fig 7, whereby motion can be imparted to the armature by the human voice or by means of a musical instrument.

The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane *a*. A cone A is used to converge sound vibrations upon the membrane. When a sound is uttered in the cone the membrane *a* is set in vibration, the armature *c* is forced to partake of the motion, and thus electrical undulations are created upon the circuit E *b e f g*. These undulations are similar in form to the air vibrations caused by the sound; that is, they are represented graphically by similar curves. The undulatory current passing through the electro-magnet *f* influences its armature *h* to copy the motion of the armature *c*. A similar sound to that uttered into A is then heard to proceed from L."

Cross-Int. 90. Please refer to Figs. 5 and 7 of the said patent of 1876, and name severally and specifically such parts of the devices represented in those figures respectively as were, in your opinion and belief, new and original with the said patentee at the date of said patent, or of the application therefor.

Ans. In my opinion, the combination of the electro-magnets, vibrating armatures, battery and line wire, shown in Fig. 5, was new; also the combination of the membranes with the vibrating armatures and electro-magnets, battery and line wire shown in Fig. 7. I do not recollect any apparatus in which an electro-magnet, armature and membrane were separately combined as shown both in the transmitter and receiver of Fig. 7.

Cross-Int. 91. Please refer to the specification of the said patent of 1876, and mention specially the several and respective parts of it, and of the statements and explanations contained therein, which at the date of said patent, or of the application therefor, were in your opinion old, or known, or in use; and also the several and respective parts of it which were then in your opinion new and original, and were not theretofore known or used. In other words, I desire you clearly to distinguish between what in your opinion is new and what is old in said specification.

Ans. The following statements seem to me to be old: —

"In Letters Patent granted to me April 6, 1875, No. 161,739, I have described a method of and apparatus for transmitting two or more telegraphic signals simultaneously along a single wire by the employment of transmitting instruments, each of which occasions a succession of electrical impulses differing in rate from the others; and of receiving-instruments, each tuned to a pitch at which it will be put in vibration to produce its fundamental note by one only of the transmitting-instruments; and of vibratory circuit-breakers operating to convert the vibratory movement of the receiving instrument into a permanent make or break (as the case may be) of a local circuit, in which is placed a Morse sounder, register, or other telegraphic apparatus. I have also therein described a form of autograph telegraph based upon the action of the above-mentioned instruments.

"In illustration of my method of multiple telegraphy I have shown in the patent aforesaid, as one form of transmitting instrument, an electro-magnet having a steel-spring armature, which is kept in vibration by the action of a local battery. This armature in vibrat-

ing makes and breaks the main circuit, producing an intermittent current upon the line-wire. I have found, however, that upon this plan the limit to the number of signals that can be sent simultaneously over the same wire is very speedily reached; for, when a number of transmitting instruments having different rates of vibration are simultaneously making and breaking the same circuit, the effect upon the main line is practically equivalent to one continuous current.

"In a pending application for Letters Patent, filed in the United States Patent Office, Feb. 25, 1875, I have described two ways of producing the intermittent current — the one by actual make and break of contact, the other by alternately increasing and diminishing the intensity of the current without actually breaking the circuit. The current produced by the latter method I shall term, for distinction sake, a 'pulsatory current.'"

. . . . . .

"Intermittent or pulsatory and undulatory currents may be of two kinds, accordingly as the successive impulses have all the same polarity or are alternately positive and negative."

. . . . . .

"It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter, and that when it is made to recede a current of opposite polarity to the first appears upon the wire. When, therefore, a permanent magnet is caused to vibrate in front of the pole of an electro-magnet an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond, in rapidity of succession, to the vibrations of the magnet, in polarity to the direction of its motion, and in intensity to the amplitude of its vibration.

"There are many ways of producing undulatory currents of electricity, dependent for effect upon the vibrations or motions of bodies capable of inductive action. A few of the methods that may be employed I shall here specify. When a wire through which a continuous current of electricity is passing is caused to vibrate in the neighborhood of another wire, an undulatory current of electricity is induced in the latter. When a cylinder upon which are arranged bar-magnets is made to rotate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet.

"Undulations are caused in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration of the conducting-wire itself in the neighborhood of such bodies. Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery.

The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart."

The following statements are, in my opinion, new: —

"The advantages I claim to derive from the use of an undulatory current in place of a merely intermittent one are, first, that a very much larger number of signals can be transmitted simultaneously on the same circuit; second, that a closed circuit and single main battery may be used; third, that communication in both directions is established without the necessity of special induction-coils; fourth, that cable-despatches may be transmitted more rapidly than by means of an intermittent current or by the methods at present in use, for, as it is unnecessary to discharge the cable before a new signal can be made, the lagging of cable-signals is prevented; fifth, and that as the circuit is never broken a spark-arrester becomes unnecessary."

. . . . . .

"Thus, when electrical undulations of different rates are simultaneously induced in the same circuit, an effect is produced exactly analogous to that occasioned in the air by vibration of the inducing bodies. Hence, the coexistence upon a telegraphic circuit of electrical vibrations of different pitch is manifested, not by the obliteration of the vibratory character of the current, but by peculiarities in the shapes of the electrical undulations, or, in other words, by peculiarities in the shapes of the curves which represent those undulations."

. . . . . .

"The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current."

. . . . . .

"In illustration of the method of creating electrical undulations, I shall show and describe one form of apparatus for producing the effect. I prefer to employ for this purpose an electro-magnet A, Fig. 5, having a coil upon only one of its legs *b*. A steel-spring armature *c*, is firmly clamped by one extremity to the uncovered leg *d* of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature *c* can be set in vibration in a variety of ways, one of which is by wind, and, in vibrating, it produces a musical note of a certain definite pitch.

"When the instrument A is placed in a voltaic circuit, *g b e f g*, the armature *c* becomes magnetic, and the polarity of its free end is opposed to that of the magnet underneath. So long as the armature *c* remains at rest, no effect is produced upon the voltaic current; but the moment it is set in vibration to produce its musical note, a

powerful inductive action takes place, and electrical undulations traverse the circuit *g b e f g*. The vibratory current passing through the coil of the electro-magnet *f* causes vibration in its armature *h* when the armatures *c h* of the two instruments A I are normally in unison with one another; but the armature *h* is unaffected by the passage of the undulatory current when the pitches of the two instruments are different.

"A number of instruments may be placed upon a telegraphic circuit, as in Fig. 6. When the armature of any one of the instruments is set in vibration, all the other instruments upon the circuit which are in unison with it respond, but those which have normally a different rate of vibration remain silent. Thus if A, Fig. 6, is set in vibration, the armatures of A^1 and A^2 will vibrate also, but all the others on the circuit will remain still. So if B^1 is caused to emit its musical note the instruments B B^2 respond. They continue sounding so long as the mechanical vibration of B^1 is continued, but become silent with the cessation of its motion. The duration of the sound may be used to indicate the dot or dash of the Morse alphabet, and thus a telegraphic dispatch may be indicated by alternately interrupting and renewing the sound. When two or more instruments of different pitch are simultaneously caused to vibrate, all the instruments of corresponding pitches upon the circuit are set in vibration, each responding to that one only of the transmitting-instruments with which it is in unison. Thus the signals of A, Fig. 6, are repeated by A^1 and A^2, but by no other instrument upon the circuit; the signals of B^2 by B and B^1, and the signals of C^1 by C and C^2 — whether A, B^2, and C^1 are successively or simultaneously caused to vibrate. Hence by these instruments two or more telegraphic signals or messages may be sent simultaneously over the same circuit without interfering with one another.

"I desire here to remark that there are many other uses to which these instruments may be put, such as the simultaneous transmission of musical notes, differing in loudness as well as in pitch, and the telegraphic transmission of noises or sounds of any kind.

"When the armature *c*, Fig. 5, is set in vibration the armature *h* responds not only in pitch but in loudness. Thus, when *c* vibrates with little amplitude, a very soft musical note proceeds from *h*; and when *c* vibrates forcibly, the amplitude of the vibration of *h* is considerably increased, and the resulting sound becomes louder. So, if A and B, Fig. 6, are sounded simultaneously (A loudly and B softly), the instruments A^1 and A^2 repeat loudly the signals of A, and B^1 B^2 repeat softly those of B.

"One of the ways in which the armature *c*, Fig. 5, may be set in vibration has been stated above to be by wind. Another mode is shown in Fig. 7, whereby motion can be imparted to the armature by the human voice or by means of a musical instrument.

"The armature *c*, Fig. 7, is fastened loosely by one extremity to

the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched-membrane, *a*. A cone, A, is used to converge sound-vibrations upon the membrane. When a sound is uttered in the cone the membrane *a* is set in vibration, the armature *c* is forced to partake of the motion, and thus electrical undulations are created upon the circuit E *b e f g*. These undulations are similar in form to the air vibrations caused by the sound — that is, they are represented graphically by similar curves. The undulatory current passing through the electro-magnet *f* influences its armature *h* to copy the motion of the armature *c*. A similar sound to that uttered into A is then heard to proceed from L.

"In this specification the three words 'oscillation,' 'vibration,' and 'undulation' are used synonymously, and in contradistinction to the terms 'intermittent' and 'pulsatory.' By the term 'body capable of inductive action,' I mean a body which, when in motion, produces dynamical electricity. I include in the category of bodies capable of inductive action, brass, copper, and other metals, as well as iron and steel."

The matter contained in the following statements as a whole I have not seen formally stated in any publication previous to Mr. Bell's patent, although most of the facts stated were a part of the common stock of scientific knowledge to the extent that a scientific man would have been able to make these statements if the questions involved had arisen in his mind.

"The electrical movement, like the aerial motion, can be represented by a sinusoidal curve or by the resultant of several sinusoidal curves."

. . . . . .

"That the difference between an undulatory and an intermittent current may be more clearly understood, I shall describe the condition of the electrical current when the attempt is made to transmit two musical notes simultaneously — first upon the one plan, and then upon the other. Let the interval between the two sounds be a major third; then their rates of vibration are in the ratio of 4 to 5. Now, when the intermittent current is used, the circuit is made and broken four times by one transmitting instrument in the same time that five makes and breaks are caused by the other. A and B, Figs. 1, 2, and 3, represent the intermittent currents produced, four impulses of B being made in the same time as five impulses of A. *c c c*, etc., show where and for how long time the circuit is made, and *d d d*, etc., indicate the duration of the breaks of the circuit. The line A and B shows the total effect upon the current when the transmitting instruments for A and B are caused simultaneously to make and break the same circuit. The resultant effect depends very

much upon the duration of the make relatively to the break. In Fig. 1 the ratio is as 1 to 4; in Fig. 2, as 1 to 2, and in Fig. 3 the makes and breaks are of equal duration. The combined effect, A and B, Fig. 3, is very nearly equivalent to a continuous current.

"When many transmitting instruments of different rates of vibration are simultaneously making and breaking the same circuit, the current upon the main line becomes for all practical purposes continuous.

"Next consider the effect when an undulatory current is employed. Electrical undulations, induced by the vibration of a body capable of inductive action, can be represented graphically without error, by the same sinusoidal curve which expresses the vibration of the inducing body itself, and the effect of its vibration upon the air; for as above stated, the rate of oscillation in the electrical current corresponds to the rate of vibration of the inducing body — that is, to the pitch of the sound produced. The intensity of the current varies with the amplitude of the vibration — that is, with the loudness of the sound; and the polarity of the current corresponds to the direction of the vibrating body — that is, to the condensations and rarefactions of air produced by the vibration. Hence, the sinusoidal curve A or B, Fig. 4, represents graphically the electrical undulations induced in a circuit by the vibration of a body capable of inductive action.

"The horizontal line *a d e f*, etc., represents the zero of current. The elevations *b b b*, etc., indicate impulses of positive electricity. The depressions *c c c*, etc., show impulses of negative electricity. The vertical distance *b d* or *c f* of any portion of the curve from the zero-line expresses the intensity of the positive or negative impulse at the part observed, and the horizontal distance *a a* indicates the duration of the electrical oscillation. The vibrations represented by the sinusoidal curves B and A, Fig. 4, are in the ratio aforesaid, of 4 to 5, — that is, four oscillations of B are made in the same time as five oscillations of A.

"The combined effect of A and B, when induced simultaneously on the same circuit, is expressed by the curve A + B, Fig. 4, which is the algebraical sum of the sinusoidal curves A and B. This curve A + B also indicates the actual motion of the air when the two musical notes considered are sounded simultaneously."

. . . . . .

"The external resistance may also be varied. For instance, let mercury or some other liquid form part of a voltaic circuit, then the more deeply the conducting wire is immersed in the mercury or other liquid the less resistance does the liquid offer to the passage of the current. Hence, the vibration of the conducting wire in mercury or other liquid included in the circuit occasions undulations in the current. The vertical vibrations of the elements of a battery

in the liquid in which they are immersed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery."

Cross-Int. 92. Referring to the fifth claim of said patent of 1876, will you please describe the "method" which you understand to be therein referred to, and also point out the parts of the specification which set forth and describe said "method," and state also in what sense you use the word "method"?

Ans. I understand the method of transmitting vocal or other sounds telegraphically, which is referred to in the fifth claim, to be the securing of this result by the use of electrical undulations similar in form to the vibrations of the air accompanying the vocal or other sounds which are thus transmitted. For the complete explanation of the method almost the whole body of the specification must be consulted. I use the word "method" as indicating the fundamental and necessary means by which the desired result of transmitting vocal or other sounds telegraphically by causing electrical undulations similar in form to the vibrations of the air accompanying them is secured, as independent of any particular form of apparatus which may be used.

Cross-Int. 93. Please describe the "apparatus" which you understand to be referred to in the said fifth claim in said patent of 1876, and also point out the parts of the specification which set forth and describe said "apparatus."

Ans. That specific form of the apparatus which is referred to in the fifth claim is described in the following paragraph of the specifications: —

"The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane *a*. A cone, A, is used to converge sound vibrations upon the membrane. When a sound is uttered in the cone, the membrane *a* is set in vibration, the armature *c* is forced to partake of the motion, and thus electrical undulations are created upon the circuit E *b e f g*. These undulations are similar in form to the air vibrations caused by the sound — that is, they are represented graphically by similar curves. The undulatory current passing through the electro-magnet *f* influences its armature *h* to copy the motion of the armature *c*. A similar sound to that uttered into A is then heard to proceed from L."

The specific form of the apparatus may, however, be very considerably varied, but if it transmitted vocal or other sounds telegraphically, by producing electrical undulations similar in form to the air waves accompanying the sounds, I should understand it to be an apparatus implicitly referred to in the claim.

Cross-Int. 94. What do you understand to be the meaning and force of the word "telegraphically" as used in the expression "transmitting vocal or other sounds telegraphically," in the fifth claim of said patent of 1876?

Ans. I understand that the sounds are to be transmitted from one place to another by means of such a line as is ordinarilly called "a telegraph line."

Cross-Int. 95. Said fifth claim speaks of "causing electrical undulations." In what do you understand the undulations are to be caused?

Ans. Electrical undulations will be produced in every part of the circuit.

Cross-Int. 96. State in what way or by what means, according to the language used in the specification, as you understand it, the undulations mentioned in the fifth claim of the said patent of 1876 are to be caused, and refer to the language of the specification setting forth such way or means.

Ans. There are a number of ways in which the electrical undulations may be produced. One way in which the inductive effect of a vibrating armature is employed is described fully, so far as the mere production of the undulations is concerned, in the following paragraphs: —

"In illustration of the method of creating electrical undulations, I shall show and describe one form of apparatus for producing the effect. I prefer to employ for this purpose an electro-magnet, A, Fig. 5, having a coil upon only one of its legs *b*. A steel-spring armature *c* is firmly clamped by one extremity to the uncovered leg *d* of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature *c* can be set in vibration in a variety of ways, one of which is by wind, and, in vibrating, it produces a musical note of a certain definite pitch.

"When the instrument A is placed in a voltaic circuit, *g b e f g*, the armature *c* becomes magnetic, and the polarity of its free end is opposed to that of the magnet underneath. So long as the armature

c remains at rest, no effect is produced upon the voltaic current; but the moment it is set in vibration to produce its musical note, a powerful inductive action takes place, and electrical undulations traverse the circuit *g b e f g*. The vibratory current passing through the coil of the electro-magnet *f* causes vibration in its armature *h* when the armatures *c h* of the two instruments A I are normally in unison with one another; but the armature *h* is unaffected by the passage of the undulatory current when the pitches of the two instruments are different."

That these undulations may be produced by the voice, as referred to especially in the fifth claim, the vibrations of the armature must, of course, be produced by and correspond to the air vibrations produced by the voice. A mode of doing this is described in the following paragraph: —

"The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane *a*. A cone, A, is used to converge sound vibrations upon the membrane. When a sound is uttered in the cone the membrane *a* is set in vibration, the armature *c* is forced to partake of the motion, and thus electrical undulations are created upon the circuit E *b e f g*. These undulations are similar in form to the air vibrations caused by the sound — that is, they are represented graphically by similar curves. The undulatory current passing through the electro-magnet *f* influences its armature *h* to copy the motion of the armature *c*. A similar sound to that uttered into A is then heard to proceed from L."

I do not understand, however, that the patentee limits himself to any specific mode of producing electrical undulations; and in the following paragraphs he indicates several ways in which electrical undulations in general can be produced: —

"There are many ways of producing undulatory currents of electricity, dependent for effect upon the vibrations or motions of bodies capable of inductive action. A few of the methods that may be employed I shall here specify. When a wire, through which a continuous current of electricity is passing, is caused to vibrate in the neighborhood of another wire, an undulatory current of electricity is induced in the latter. When a cylinder, upon which are arranged bar magnets, is made to rotate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coil of the electro-magnet.

"Undulations are caused in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration of the conducting wire itself in the neighborhood of such

bodies. Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery. The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current. The external resistance may also be varied. For instance, let mercury or some other liquid form part of a voltaic circuit; then the more deeply the conducting wire is immersed in the mercury or other liquid the less resistance does the liquid offer to the passage of the current. Hence, the vibration of the conducting wire in mercury or other liquid included in the circuit occasions undulations in the current. The vertical vibrations of the elements of a battery in the liquid in which they are immersed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery."

If the moving parts, by means of whose vibration the electrical undulations are produced, are actuated by vocal or other sounds and are employed to transmit these sounds telegraphically, using the method referred to in the fifth claim, they will produce electrical undulations similar to the air waves accompanying them. I should consider any particular manner in which this was done as one of the ways in which the undulations mentioned in the fifth claim might be caused.

Cross-Int. 97. In your examination in chief you have quoted from Helmholtz as follows: "Every different quality of tone requires a different form of vibration" (p. 32). State whether the words thus quoted by you are a part of a sentence, the whole of which is as follows:—

"It will be shown to be so far correct that every different quality of tone requires a different form of vibration; but on the other hand it will also appear that different forms of vibration may correspond to the same quality of tone."

Ans. They are.

Direct Examination resumed by CHAUNCEY SMITH, Esq., *of Counsel for Complainants.*

Int. 98. Will you explain briefly the meaning of those two statements in Helmholtz, or the physical facts referred to by them?

Ans. The meaning of the first statement, that every different quality of tone requires a different form of vibration, will be clear if we consider the compound periodic curve which results from the superposition of a number of elementary sinusoidal curves as shown in the figure given in my answer to Int. 11. If the curves are drawn as there shown, the compound curve can have only a definite shape or form as apparent to the eye; if this compound curve represents an acoustic vibration the quality of the sound produced by that vibration will be definite and fixed. No other quality of sound could possibly be produced by vibrations represented by the same curve. Let us suppose, however, that some of the sinuous lines at *a b* in that figure were slid horizontally along *a b*. This lateral sliding would correspond to what is called "a change of phase," among the vibrations, and such changes are constantly occurring among the partial tones constituting a musical sound. It is evident that if we were to construct a compound resultant curve, having made this change in the components, it would present to the eye a different appearance, and in this sense the curve or the vibration representing it would have a different form. The compound curve would, however, as before, be a resultant of the combination of the same elementary curves, and the quality of sound due to the vibration represented by the complex curve would be the same as before, since the partial tones into which the complex sound is resolved and on which its quality depends are the same in both cases, being represented by the same elementary sinusoidal curves. The only difference among the vibrations themselves is what is called "a difference in phase," which phase difference has no influence, or at least no material influence, on the quality of the sound. It appears from this that two curves which present very different appearances to the eye may nevertheless represent the same quality of sound, since they are composed of the same component curves. This is explained at length in the work of Helmholtz on pp. 46–55.

Int. 99. Would it be true in both cases that the forms of the

curves representing the sounds graphically would each correspond with the actual vibrations which produced the sound?

Ans. It would.

[*It is stipulated that Mr. Roberts may further examine Prof. Cross if he shall so desire after reading that portion of the cross examination which has been taken in his absence.*]

CHAS. R. CROSS.

Attest: CHAS. H. SWAN, *Special Examiner.*

BOSTON, Jan. 9, 1885.

CHARLES R. CROSS, *recalled by* MR. ROBERTS.

Int. 100. I desire to call your attention to Cross-Int. 91, and the answer thereto. Will you state briefly the circumstances under which that answer was made, and whether you desire to correct any portion of the same.

Ans. The answer referred to was made in a more hurried manner than was desirable, owing to the fact that Mr. Sheppard was anxious to close the examination in season to take an early train, therefore at his request instead of reading from the specification I indicated the paragraphs which were to be classified, by marking with a pen along the margin of a Patent Office copy of the patent. The paragraph immediately preceding the claim, and beginning, "In this specification the three words," etc., was inadvertently marked as belonging with the new matter. This does not belong to those paragraphs, and I had not intended to make any reference to it, inasmuch as it simply defines the sense in which certain terms are used in the specification. The paragraph would have been omitted by me if I had been present at the time when the examiner made up his record.

CHAS. R. CROSS.

Attest: CHAS. H. SWAN, *Special Examiner.*

BOSTON, Jan. 9, 1885.

DEPOSITION OF WILLIAM C. TOMPKINS.

Direct Examination by GEORGE L. ROBERTS, Esq., *of Counsel for Complainants.*

Int. 1. State your name, age, residence, and occupation.

Ans. William C. Tompkins; I am forty-one years old; I live in Boston, and am in the employ of the American Bell Telephone Company.

Int. 2. What is the nature of your duties in connection with the American Bell Telephone Company, and what familiarity have you acquired with the construction of telephonic instruments?

Ans. My duties are especially in connection with the discovery and prosecution of infringements on the company's patents. I have been engaged in this work about four years, and my duties have necessitated an acquaintance with telephonic apparatus of all kinds.

Int. 3. If you obtained any knowledge of the acts of the defendant company prior to April 24, 1884, relating to the manufacture and use of telephones, please state what it was and when obtained.

Ans. In January, 1884, I learned of the incorporation of the defendant company, and obtained from the Secretary of State of New Jersey a certified copy of their certificate of incorporation, which copy I now have in my possession and here produce. Shortly after this I learned that the said company had established an office in Philadelphia. In the latter part of February, 1884, I called at their said office, which was located at 1017 Chestnut Street, Philadelphia, Penn. On the doors of the offices were painted the names of the company and of its officers. At that time and place I had an interview with a gentleman who stated that he was the secretary of said company. In reply to inquiries made by me he said that the company were going ahead at once to put out telephones; that they should establish an exchange at once in Philadelphia, and were then ready to furnish telephones for private lines. In compliance with my desire to be shown the instruments which they intended offering the public, he showed me two set of telephones which were fastened

to the wall and connected up in apparent condition for use. He said they were connected with two private lines, one of which ran to the shop of the company in West Philadelphia, and the other to some point which I have forgotten. With his permission I carried on a conversation over the line running to the shop with some party at that point, to me unknown, and found the instruments adapted for conversational purposes.

Later, on the same day, I called at the shop of the company in West Philadelphia, to which I have made reference as being connected with the office by telephone. I there saw and had a conversation with Mr. Henry Clay, the patentee of certain special devices shown in the defendants' instruments. Mr. Clay made substantially the same statement as to the plans of the company as had previously been made to me by the secretary. He was at work upon a switch board, which he informed me was intended for their Philadelphia telephone exchange. I saw at such shop a set of telephones attached to the wall, connected up in an apparent condition for use; also saw various parts of the said instrument lying upon the bench in course of manufacture. These instruments, as well as those I had seen at the office of the company, were identical, in all respects, with Exhibit Defendants' Transmitter and Exhibit Defendants' Receiver now shown me, and marked as exhibits in this cause.

In the latter part of February or first part of March, 1884, I had an interview, in Philadelphia, with Mr. James A. Palmer, the general superintendent of the defendant company, who informed me that the company were then at work constructing a telephone exchange, and that they had rented for that purpose the upper portion of the building located at the southwest corner of Third and Chestnut Streets, Philadelphia. I went to this building and ascertained that his statements in this respect were true, workmen being then engaged in erecting fixtures for a telephone exchange. In the first week of March, I learned through the subscribers to the Bell Telephone Exchange, in Philadelphia, that the defendant company had issued and were distributing a circular and a blank form of contract, in which they solicited subscriptions to their telephone exchange thereafter to be established. I now produce a copy of said circular and

blank form of contract, which came into my possession on or about the eleventh day of March, 1884.

On the twenty-third day of April, 1884, I visited the office of Gregg Brothers, 18 South Front Street, Philadelphia. I there saw attached to the wall, in apparent condition for use, a set of telephones identical with those I had previously seen at the office and shop as above specified. I had a conversation with a gentleman in the office, who informed me that he was a Mr. Gregg, of said firm, in which he informed me that the said telephones were procured from the Clay Commercial Telephone Company, and they were on a private line connecting his office with the office of Collis & Levy, brokers, 138 South Third Street, Philadelphia. He allowed me to talk over the line, and I carried on a short conversation with some person at Collis & Levy's, who responded to my call. On the transmitter were stamped the following words and figures : —

"CLAY PATENTS
1883
PROPERTY OF
CLAY COMMERCIAL
5
TELEPHONE CO."

I then went to the office of Collis & Levy, where I saw fastened to the wall a set of telephones like those I had seen at Gregg Brothers. I asked permission to talk with Gregg Brothers over the line, but was not allowed to do so.

[*Counsel for complainants puts in evidence the certified copy of the certificate of incorporation of the Clay Commercial Telephone Company produced by this witness, and the same is marked "Exhibit Defendants' Certificate of Incorporation;" also the circular produced by this witness, which is marked "Exhibit Defendants' Circular"; and also the blank form of contract produced by the witness which is marked "Exhibit Defendants' Contract Blank."*]

W. C. TOMPKINS.

Attest: CHAS. H. SWAN, *Special Examiner.*

EXHIBIT DEFENDANTS' CERTIFICATE OF INCORPORATION, C. H. S., SPECIAL EXAMINER.

Certificate of Incorporation of the Clay Commercial Telephone Company.

Know all men by these presents, that we, George W. Bratton, Alonzo P. Douglass and Samuel P. Godwin, do hereby associate ourselves into a company, and being desirous of becoming incorporated (having formed said company for such purpose) under the act of the Legislature of New Jersey, entitled, An Act concerning corporations, approved the seventh day of April, eighteen hundred and seventy-five, and the several supplements to and acts amendatory of said act, do make, sign, and acknowledge this certificate in writing, and we do hereby certify: —

1*st*. *First*. That the name which we have assumed to designate such company, and to be used in its business and dealings, is the "Clay Commercial Telephone Company."

2*nd*. *Second*. That the place in this State where the business of said company is to be conducted is at No. 211½ Market Street, in the city of Camden, Camden County, New Jersey. The principal part of the business of said company within this State is to be transacted at Camden, in the county of Camden, New Jersey, and the places out of the State where the same is to be conducted are the other States of the United States and its Territories.

And that the object for which this company is formed is the purchase of the patents of Henry Clay for telephony, and the establishment of telephone stations, sub-stations, automatic exchange systems, and the building of cable lines and wires for aerial and underground telephony, and to procure, own and sell various electrical apparatus, machinery and plant used in connection therewith, and to dispose of licenses under the same, with the right to acquire, hold, dispose of and sell such property, real, personal and mixed, as may be requisite or necessary to use in such business or in connection therewith.

3*rd*. *Third*. That the total amount of the capital stock of said company shall be two million five hundred thousand dollars ($2,500,000), that the amount of said capital stock to be subscribed and paid in, with which said company shall commence business, shall be one thousand dollars ($1,000). That the capital stock shall be divided

into fifty thousand shares (50,000) of fifty dollars ($50) each, and the par value of each share shall be fifty dollars ($50).

4th. Fourth. That the names and residences of the stockholders and the number of shares held by each are as follows: —

George W. Bratton, Philadelphia, ten (10) shares.
Alonzo P. Douglass, Philadelphia, five (5) shares.
Samuel P. Godwin, Philadelphia, five (5) shares.

5th. Fifth. The period at which said company shall commence its business shall be the 21st day of November, eighteen hundred and eighty-three, and terminate its business on the 21st day of November, nineteen hundred and thirty-three.

In witness whereof, we have hereunto set our hands and seals this 20th day of November, in the year of our Lord eighteen hundred and eighty-three.

GEORGE W. BRATTON. [L. S.]
ALONZO P. DOUGLASS. [L. S.]
SAM'L. P. GODWIN. [L. S.]

Signed, sealed and delivered in the presence of

SAMUEL L. TAYLOR,
GEO. L. CRAWFORD.

STATE OF PENNSYLVANIA,
COUNTY OF PHILADELPHIA, ss.

Be it remembered that on this 20th day of November, A. D. 1883, before me, the subscriber, a commissioner of deeds, etc., for the State of New Jersey, here resident and duly appointed and qualified, personally appeared George W. Bratton, Alonzo P. Douglass and Samuel P. Godwin, who I am satisfied are the persons named in and who executed the foregoing certificate, and I having first made known to them the contents thereof, they did each acknowledge that they signed, sealed and delivered the same as their voluntary act and deed, all of which is hereby certified.

[L. S.] SAMUEL L. TAYLOR,
Commissioner for New Jersey.

STATE OF PENNSYLVANIA,
COUNTY OF PHILADELPHIA, SS.

Be it remembered that on this 20th day of November, A. D. 1883, before me, the subscriber, a commissioner of deeds, etc., for the State of New Jersey, here resident and duly appointed and qualified, personally appeared George L. Crawford, who, being by me duly sworn, on his oath did depose and say that he saw George W. Bratton, Alonzo P. Douglass and Samuel P. Godwin sign, seal and deliver the foregoing certificate as their voluntary act and deed, and that deponent at the same time subscribed his name thereto as a witness to the execution thereof.

GEORGE L. CRAWFORD.

Sworn to and subscribed this twentieth day of November A. D. 1883.

[L. S.] SAMUEL L. TAYLOR,
Commissioner for New Jersey.

[ENDORSED.]

Received Nov. 21st, 1883 and recorded in the Clerk's Office of Camden County at Camden, in Book No. 2 of Corporations, page 334, etc.

JOS. C. HOLLINSHEAD, *Clerk.*

STATE OF NEW JERSEY,
DEPARTMENT OF STATE.

I, Henry C. Kelsey, Secretary of State of the State of New Jersey, do hereby certify, that the foregoing is a true copy of Certificate of Incorporation of the Clay Commercial Telephone Company, as the same is taken from and compared with the original filed November 22nd, 1883, now remaining on file in my office.

In testimony whereof, I have hereunto set my hand and affixed my official seal, at Trenton, this twenty-fourth day of January, A. D. 1884.

[SEAL] (Signed) HENRY C. KELSEY,
Secretary of State.

into fifty thousand shares (50,000) of fifty dollars ($50) each, and the par value of each share shall be fifty dollars ($50).

4*th*. *Fourth*. That the names and residences of the stockholders and the number of shares held by each are as follows: —

George W. Bratton, Philadelphia, ten (10) shares.
Alonzo P. Douglass, Philadelphia, five (5) shares.
Samuel P. Godwin, Philadelphia, five (5) shares.

5*th*. *Fifth*. The period at which said company shall commence its business shall be the 21st day of November, eighteen hundred and eighty-three, and terminate its business on the 21st day of November, nineteen hundred and thirty-three.

In witness whereof, we have hereunto set our hands and seals this 20th day of November, in the year of our Lord eighteen hundred and eighty-three.

GEORGE W. BRATTON. [L. S.]
ALONZO P. DOUGLASS. [L. S.]
SAM'L. P. GODWIN. [L. S.]

Signed, sealed and delivered in the presence of

SAMUEL L. TAYLOR,
GEO. L. CRAWFORD.

STATE OF PENNSYLVANIA,
COUNTY OF PHILADELPHIA, SS.

Be it remembered that on this 20th day of November, A. D. 1883, before me, the subscriber, a commissioner of deeds, etc., for the State of New Jersey, here resident and duly appointed and qualified, personally appeared George W. Bratton, Alonzo P. Douglass and Samuel P. Godwin, who I am satisfied are the persons named in and who executed the foregoing certificate, and I having first made known to them the contents thereof, they did each acknowledge that they signed, sealed and delivered the same as their voluntary act and deed, all of which is hereby certified.

[L. S.] SAMUEL L. TAYLOR,

STATE OF PENNSYLVANIA,
COUNTY OF PHILADELPHIA, SS.

Be it remembered that on this 20th day of November, A. D. 1883, before me, the subscriber, a commissioner of deeds, etc., for the State of New Jersey, here resident and duly appointed and qualified, personally appeared George L. Crawford, who, being by me duly sworn, on his oath did depose and say that he saw George W. Bratton, Alonzo P. Douglass and Samuel P. Godwin sign, seal and deliver the foregoing certificate as their voluntary act and deed, and that deponent at the same time subscribed his name thereto as a witness to the execution thereof.

GEORGE L. CRAWFORD.

Sworn to and subscribed this twentieth day of November A. D. 1883.

[L. S.] SAMUEL L. TAYLOR,
Commissioner for New Jersey.

[ENDORSED.]

Received Nov. 21st, 1883 and recorded in the Clerk's Office of Camden County at Camden, in Book No. 2 of Corporations, page 334, etc.

JOS. C. HOLLINSHEAD, *Clerk.*

STATE OF NEW JERSEY,
DEPARTMENT OF STATE.

I, Henry C. Kelsey, Secretary of State of the State of New Jersey, do hereby certify, that the foregoing is a true copy of Certificate of Incorporation of the Clay Commercial Telephone Company, as the same is taken from and compared with the original filed November 22nd, 1883, now remaining on file in my office.

In testimony whereof, I have hereunto set my hand and affixed my official seal, at Trenton, this twenty-fourth day of January, A. D. 1884.

[SEAL] (Signed) HENRY C. KELSEY,
Secretary of State.

EXHIBIT DEFENDANTS' CIRCULAR, C. H. S., SPECIAL EXAMINER.

CLAY COMMERCIAL TELEPHONE CO.

THE CLAY COMMERCIAL TELEPHONE CO. is chartered by the State of New Jersey, and has ample capital to prosecute its work.

The Company claims for its instruments simplicity of construction, giving additional power, distinct articulation, automatic disconnection with central office, and absolute privacy.

The Board of Directors is composed of active and well-known business men of Philadelphia who have invested their money in the enterprise, and their names are sufficient guarantee that the business of the Company will be pushed with energy and vigor.

The Company also claims, by reason of the greater advantages possessed by them, to be able to furnish a much cheaper and more reliable telephone service than has been heretofore accomplished.

Several Exchanges will shortly be opened, and they solicit the privilege of placing their instruments on 30 days' trial in the offices of reliable and responsible firms or individuals with the understanding, that if entirely satisfactory, a contract can be made for one year.

RATES.

WITHIN A MILE OF ANY EXCHANGE.

Business Houses (special wire) . . .	$80 00 per year.
Lawyers and Physicians (special wire) . .	65 00 "
Residences (three on a wire)	50 00 "

For distances exceeding a mile at rate of $40 per mile.

PAYABLE QUARTERLY IN ADVANCE.

LOSS OF SERVICE.

Twenty-four hours after notice of same has been given in writing, a rebate will be made for each and every day that service is delayed, and the amount deducted from the next quarterly bill.

Estimates for Private Lines and any desired information will be cheerfully furnished at the office of the Company.

JAMES A. PALMER,
General Supt.

No. 1017 CHESTNUT STREET,
PHILADELPHIA, PA.

CLAY COMMERCIAL TELEPHONE CO.,

GENERAL OFFICE,

SHAKESPEARE BUILDING,

1017 CHESTNUT STREET, PHILADELPHIA.

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EXHIBIT DEFENDANTS' CONTRACT BLANK, C. H. S., SPECIAL EXAMINER.

PHILADELPHIA, March, 1884.

We, the undersigned, hereby request the Clay Commercial Telephone Co., to place in our offices their instruments, and to connect same with their exchange system, with the understanding that if their service is satisfactory on thirty days' trial, we will contract for Telephone service for one year, at the rate of $, within a mile of their exchange.

.....

Dear Sir: .

If the above should meet with your approval, please sign and return, and oblige,

Respectfully,

JAMES A. PALMER,

General Supt.

MATTER OFFERED IN EVIDENCE BY COUNSEL FOR COMPLAINANTS DURING THE TAKING OF PROOFS FOR DEFENDANTS.

(*See Defendants' Proofs, p.* 89.)

General Report of Judges of Centennial Exhibition, Group XXV. (pp. 20, 21.)

[*Dolbear Record*, pp. 93, 94.]

THE ELECTRIC TELEPHONE AND MULTIPLE TELEGRAPH.

"The idea of transmitting sounds to a distance by means of electrical currents has been for several years before the world, and the idea of extension of this to telegraphy was evident, though no one had thought it could lead to practical results. But the idea of a multiple electrophonic telegraph transmitting simultaneously several different musical notes for the simultaneous transmission of different messages by one wire, is an invention of high scientific character promising admirable practical results. For the honor of this invention there are two claimants, Mr. Elisha Gray, of Chicago, Illinois, and Mr. Alexander G. Bell, of Salem, Massachusetts. These inventions are independent of one another and different in the method of producing the result. In the telegraph of Mr. Gray several series of waves or impulses are simultaneously transmitted through a single wire. These impulses are excited by interruptions in the current produced by tuning-forks of different pitches, and excite, at the farther extremity of the line, corresponding variations in tuning-forks of the same pitch. Thus, if four or five tuning-forks are vibrated at the same time at one end of the line, each will excite vibrations in its corresponding fork at the other end without affecting the other forks. The exhibitors of this telegraph inform the judges that they are now able to equip lines for actual business with a capacity for carrying, through one wire, eight messages simultaneously, and there is no reason why the number may not be increased to sixteen. This telegraph may be made self-recording, or may be worked forward by relays through greater lengths of line than the insulation allows in one circuit.

"The telephone of Mr. Bell aims at a still more remarkable result, — that of transmitting audible speech through long telegraphic lines. In the improved instrument the result is produced with striking effect, without the employment of an electrical current other than that produced by the mechanical action of the impulse of the breath as it issues from the lungs in producing articulate sounds. To understand this wonderful result, suppose a plate of sheet-iron,

about five inches square, suspended vertically before the mouth of the speaker so as to vibrate freely by the motion of the air due to the speech, and suppose also another iron plate, of the like dimensions, similarly suspended before the ear of the hearer of the sound, and between these, but not in contact with them, is stretched the long telegraphic wire. Each end of this wire is attached to two coils of insulated wire surrounding a core of soft iron, the ends of which are placed near the middle of the plate, but not in contact with it. These four cores are kept in a magnetic condition by being attached at each end of the line to the two poles of a permanent magnet. Now it is evident that in this arrangement any disturbance of the magnetism of one of the permanent magnets, increasing or diminishing it, will induce electrical currents, which, traversing the long wire, will produce a similar disturbance of the magnetism of the arrangement at the other end of the wire. Such a disturbance will be produced by the vibration of the plate of soft iron due to the words of the speaker, and the current thus produced, changing the magnetism of the soft iron cores, will by reaction produce corresponding vibrations in the iron plate suspended before the ear of the hearer. The vibrations of the second plate being similar to those of the first, will reproduce the same sounds. Audible speech has, in this way, been transmitted to a distance of three hundred miles, perfectly intelligible to those who have become accustomed to the peculiarities of certain of the sounds. All parts of a tune are transmitted with great distinctness and with magical effect.

"This telephone was exhibited in operation at the Centennial Exhibition, and was considered by the judges the greatest marvel hitherto achieved by the telegraph. The invention is yet in its infancy, and is susceptible of great improvements."

REPORTS ON AWARDS, GROUP XXV. CENTENNIAL EXHIBITION (pp. 130, 131).

[DOLBEAR RECORD, pp. 95–97.]

"3. ALEXANDER GRAHAM BELL, SALEM, MASS., U. S.

"GRAHAM BELL'S ELECTRIC TELEPHONE AND MULTIPLE TELEGRAPH.

"*Report.*—The idea of an electric telephone, or apparatus for transmitting sounds to a distance by variations of electric current through a wire, has been for many years before the world, and has been realized in several ways, differing considerably in details as to the appliances at two points of the circuit for producing the variations of electric current, and for deriving perceptible effects from them. An extension of this idea to some kind of electro-phonetic telegraphy was inevitable, even though no one had thought it might or could lead to practically useful results. But the idea of a mul-

tiple electro-phonetic telegraph transmitting simultaneously several different musical notes, and using intermissions of these (like intermissions of currents in so many separate wires) for the simultaneous and independent transmission of different messages by one wire, is a very fine invention, of high scientific character, promising splendidly useful practical results.

"This invention is claimed by Mr. Graham Bell, and he is entitled to full credit for it, even though, as I believe is the case, it has been also independently invented by others, both in England and America.

"A very well worked-out realization of it is given in Mr. Bell's apparatus now exhibited. A great practical advantage of the electro-phonetic multiple telegraph over other methods of multiple telegraphy through one wire, is that no adjustment is required for varying conditions of the line to render the non-interference among the different messages perfect. Another even more important practical advantage is that it is indifferent between what points of the line and in which directions the different messages are being sent. The different messages can, in fact, be transmitted from any different points of the line, and each may be read at all other stations (whether stations from which others of the messages are being sent or not), with practically perfect non-interference. Another important advantage is that earth currents and lightning discharges will never disturb the signaling.

"Mr. Graham Bell's apparatus includes an ingenious and effective instrument for automatically making and breaking an electric contact every time one of his telegraphic musical notes commences and ceases to sound. Thus his multiple telegraph may be made self-recording (after the Morse or Bain method), or may be worked forward by relay through greater lengths of line than imperfectness of the insulation allows to be worked in one circuit. Mr. Bell showed me in action two of these electrophonic relays recording quite independently the transmission of independent messages by two musical notes in one wire.

"In addition to his electro-phonetic multiple telegraph, Mr. Graham Bell exhibits apparatus by which he has achieved a result of transcendent scientific interest, — the transmission of spoken words by electric currents through a telegraph wire. To obtain this result, or even to make a first step towards it, — the transmission of different qualities of sounds, such as the vowel sounds, — Mr. Bell perceived that he must produce a variation of strength of current in the telegraph wire as nearly as may be in exact proportion to the velocity of a particle of air moved by the sound; and he invented a method of doing so, a piece of iron attached to a membrane, and thus moved to and fro in the neighborhood of an electro-magnet, which has proved perfectly successful. The battery and wire of this electro-magnet are in circuit with the telegraph wire and the wire of another electro-magnet at the receiving station. This second electro-magnet

has a solid bar of iron for core, which is connected at one end by a thick disk of iron to an iron tube surrounding the coil and bar. The free circular end of the tube constitutes one pole of the electro-magnet, and the adjacent free end of the bar core the other. A thin, circular iron disk, held pressed against the end of the tube by the electro-magnetic attraction, and free to vibrate through a very small space without touching the central pole, constitutes the sounder by which the electric effect is reconverted into sound. With my ear pressed against this disk, I heard it speak distinctly several sentences, first of simple monosyllables, 'To be or not to be' (marvellously distinct); afterwards sentences from a newspaper, 'S. S. Cox has arrived' (I failed to hear the 'S. S. Cox,' but the 'has arrived' I heard with perfect distinctness); then 'City of New York,' 'Senator Morton,' 'The Senate has passed a resolution to print one thousand extra copies,' 'The Americans of London have made arrangements to celebrate the Fourth of July.' I need scarcely say I was astonished and delighted; so were others, including some other judges of our Group, who witnessed the experiments, and verified with their own ears the electric transmission of speech. This, perhaps the greatest marvel hitherto achieved by the electric telegraph, has been obtained by appliances of quite a homespun and rudimentary character. With somewhat more advanced plans and more powerful apparatus, we may confidently expect that Mr. Bell will give us the means of making voice and spoken words audible through the electric wire to an ear hundreds of miles distant."

[The judges were Joseph Henry, Sir William Thomson, J. E. Hilgard, James C. Watson, H. K. Oliver, F. A. P. Barnard, J. Schudmayer, E. Levasseur, P. F. Kupka, Ed. Favre-Perret, Chas. E. Emery.]

NEWSPAPER PUBLICATIONS IN 1876 AND 1877.

[*Dolbear Record, between pages* 87 *and* 166.]

The *Boston Evening Transcript*, July 8, 1876: —

Notes at the Centennial.— " . . . Professor Bell has also a telegraphic and telephonic apparatus in this department for the transmission of many messages over a single wire, and of musical and articulate sounds by telegraph. The experiments which have been made in the presence of the Emperor of Brazil, Sir William Thomson, and others interested in the subject, have been highly interesting and satisfactory in their results."

The New York *Evening Post*, Sept. 5, 1876: —

"Yet the telegraphic and telephonic apparatus invented by A. Graham Bell should reconcile us to this loss. . . . Professor Bell has sent a valuable collection that well illustrates the mode by which many messages may be transmitted over a single wire, and also the ease with which musical and articulate sounds may be transmitted by telegraph. . . . Spoken words may be thus transmitted."

The *Boston Daily Advertiser*, Sept. 25, 1876: —

"The following passage, taken from the opening address of Prof. Sir William Thomson, on assuming the chair of the section of physical science at the Glasgow meeting of the British Association, will be read with interest, as showing the impression made upon an English student of science, by our progress in discovery and in practical science: 'In the Canadian department, I heard, "To be or not to be," "There's the rub," through an electric telegraph wire; but scorning monosyllables, the electric articulation rose to higher flights, and gave me passages taken at random from the New York newspapers: "S. S. Cox has arrived" (I failed to make out the "S. S. Cox,") "The City of New York," "Senator Morton," "The Senate has resolved to print a thousand extra copies." "The Americans in London have resolved to celebrate the coming Fourth of July." All this my own ears heard, spoken to me with unmistakable distinctness by the thin circular disk armature of just such another little electro-magnet as this which I hold in my hand. The words were shouted with a clear and loud voice by my colleague judge, Professor Watson, at the far end of the line, holding his mouth to a close stretched membrane, such as you see before you here, carrying a little piece of soft iron, which was thus made to perform, in the neighborhood of an electrio-magnet in circuit with the line, motions proportional to the sonorific motion of the air.

"'This, the greatest by far of all the marvels of the electric telegraph, is due to a young countryman of our own, Mr. Graham Bell, of Edinburgh and Montreal and Boston, now becoming a naturalized citizen of the United States. Who can but admire the hardihood of invention which devised such very slight means to realize the mathematical conception that, if electricity is to convey all the delicacies of quality which distinguish articulate speech, the strength of its current must vary continuously, and as nearly as may be in simple proportion to the velocity of a particle of air engaged in constituting the sounds?'"

The *Boston Daily Advertiser*, Oct. 14, 1876: —

"At a meeting of the American Academy on Wednesday evening, Professor Bell exhibited his wonderful discovery by which sounds may be transmitted through wires by means of the electric current. By the invention of peculiar apparatus, conversation may be carried through hundreds of miles of wires with the greatest ease."

The *Scientific American*, Sept. 9, 1876: —

"THE HUMAN VOICE TRANSMITTED BY TELEGRAPH.

"Several weeks ago we gave a sketch and description of the thread telegraph, consisting of two small tin or wooden cylinders, each having a membrane stretched over one end, the two membranes connected by a stout thread.

"Professor Graham Bell, by a device somewhat analogous, has succeeded in transmitting the tones of the human voice by telegraph. Instead of the thread, he connects the membranes of the two cylinders or drums with the armatures of the electro-magnets, one drum being placed at each end of the telegraph wire. In fact, he not long ago demonstrated the possibility of conveying vocal sounds by means of the ordinary telegraph wires and special appliances for transmitting and receiving the sounds. The apparatus used by Professor Bell is thus described: Two single-pole electro-magnets, each having a resistance of ten ohms, were arranged in circuit with a battery of five carbon elements, the total resistance being about twenty-five ohms. A drumhead of goldbeater's skin, about two and three fourths inches in diameter, was placed in front of each electro-magnet, and a circular piece of clock spring was glued to the middle of the membrane of each drumhead. One of these telephones was placed in the experimental room, and the other in the basement of an adjoining house. Upon singing into the telephone the sounds of the voice were reproduced by the instrument in the distant room; and if two persons sang simultaneously, the two notes were audible at the other telephone.

"At the time of the lecture, an experiment was made to show the transmission of articulate speech, an assistant going into the adjoining building

familiar questions were, it is said, understood after a few repetitions. The vowel sounds alone are those faithfully reproduced. Diphthongal sounds and rotund vowels are readily distinguished, but consonants are generally unrecognizable. Now and then, however, a sentence comes out with almost startling distinctness, the consonants as well as the vowels being clearly audible. Professor Bell stated that telephonic effects can be produced with three varieties of currents, — the intermittent, the pulsatory, and the undulatory. The first are characterized by the alternate presence and absence of electricity in the circuit, the pulsatory current by sudden changes in intensity, while undulatory currents are obtained by gradual changes analogous to the changes of density of air produced by vibrations of a pendulum.

"The most recent trial of Professor Bell's instrument was at his residence, Brantford, Canada, Aug. 11. The Toronto *Globe* states that instruments were placed, one in the porch of the residence, and the other in an outhouse on the grounds, and communication between these made by ten miles of wire. Musical notes, the human voice, and songs spoken and sung before one instrument were plainly audible by placing the instrument to the ear at the other. By this invention, too, any number of messages can be conveyed over one wire in either direction, provided they have a different pitch; the tones of the voice can pass over the electric wire, enabling the hearer at any distance to hear distinctly what is said, and to distinguish the voice of the speaker. On Aug. 10 the professor had communication made with his instrument on the common telegraph wire between Brantford and Mount Pleasant (five miles), and was spoken with, while in Mount Pleasant, by Professor D. C. Bell and Mr. Griffin, from the *Dominion* office, in Brantford. On the evening of Aug. 12 the professor tried a new experiment, having had an instrument made so that three persons could sing different tunes, or different parts of the same tune, into the instrument at the same time. The trial was perfectly successful, the different voices coming distinctly over the wire at the same time, so that they could be separately distinguished by the listener. The practical exemplification of the lately discovered system of telephony made by the professor afforded much pleasure and information to those present."

Boston Daily Advertiser, Oct. 19, 1876: —

TELEPHONY.

Audible Speech Conveyed Two Miles by Telegraph.

Professor A. Graham Bell's Discovery. — Successful and Interesting Experiments. — The Record of a Conversation carried on between Boston and Cambridgeport.

The following account of an experiment made on the evening of

Oct. 9 [1876], by Alexander Graham Bell and Thomas A. Watson, is interesting, as being the record of the first conversation ever carried on by word of mouth over a telegraph wire. Telephones were placed at either end of a telegraph line owned by the Walworth Manufacturing Company, extending from their office in Boston, to their factory in Cambridgeport, a distance of about two miles. The company's battery, consisting of nine Daniell cells, was removed from the circuit, and another, of ten carbon elements, substituted. Articulate conversation then took place through the wire. The sounds, at first faint and indistinct, became suddenly quite loud and intelligible. Mr. Bell, in Boston, and Mr. Watson, in Cambridge, then took notes of what was said and heard, and the comparison of the two records is most interesting, as showing the accuracy of the electrical transmission: —

Boston Record.

Mr. Bell. What do you think was the matter with the instruments?

Mr. Watson. There was nothing the matter with them.

B. I think we were both speaking at the same time.

W. Can you understand anything I say?

B. Yes; I understand everything you say.

W. The reason why you did not hear at first was because there was a relay in the circuit.

B. You may be right, but I found the magnet of my telephone touching the membrane.

W. I cut this relay out, and then the sounds came perfectly.

B. I hear every syllable. Try something in an ordinary conversational voice.

W. Shall I connect their battery in the circuit?

B. No; there is no necessity to connect their battery in the circuit; for the sounds come out quite loudly.

W. I am now talking in quite a low tone of voice.

B. The sounds are quite as loud as before, and twice as distinct.

W. Cut out the battery, and then talk.

B. All right; I will cut out the battery now, if you will keep listening.

Cambridge Record.

Mr. Bell. What do you think is the matter with the instruments?

Mr. Watson. There is nothing the matter with them.

B. I think . . at the same time.

W. Can you understand anything I say?

B. Yes; I understand everything you say.

W. The reason why it did not work at first was because there was a relay in the circuit.

B. You may be right, but I find that my touches the membrane.

W. I cut the relay out, and then the sounds came perfectly.

B. I hear every syllable. Try something in a conversational voice.

W. Shall I connect their battery in the circuit?

B. No; there is no necessity for putting their battery in the circuit, as the sounds come out quite loudly.

W. I am now talking in quite a low tone of voice.

B. The sounds are quite as loud as before, and quite as distinct.

W. Cut out the battery and then talk.

B. All right; I will cut out the battery now, if you will keep listening.

[Here an interruption occurred, and after a short time Mr. Bell said:]

B. I thought you were going to say something.
W. Is the battery cut out?
B. No; but I will do it now.

B. I thought you were going to say something.
W. Is the battery cut out?
B. No; but I will do it now.

[Battery having been cut out, Mr. Bell continued:]

B. Do you hear anything now?

[Battery replaced.]

B. Did you hear anything?
W. No; not a sound.
B. Say something to me when I cut out the battery again.

B. Did you hear anything?
W. No; not a sound.
B. Say something to me when I cut out the battery again.

[Battery cut out.]

W. . . . . .
. . . . . .

W. I could not hear a sound when the battery was cut out.

[Battery replaced.]

B. I fancy I heard a trace of your voice.
W. Shall I put on our battery, to see if it increases the effect?
B. I'll tell you what we'll do. We'll take off our battery, and put on theirs, as before.

B. I fancy I heard a trace of your voice.
W. Shall I put on their battery, to see if it increases the effect?
B. I'll tell you what we'll do. We'll take off our battery altogether, and put on theirs, as before.

[The company's batteries having been placed in circuit, faint and indistinct sounds were heard at the Boston end, and then came the intelligible sentence:]

W. Is our battery off?
B. Yes, our battery is off. What have you been doing? The sounds were quite soft at first, but now they are quite loud.
B. Shall I put in our battery again?
W. (Indistinctly heard.) That was very indistinct. Put on our battery.

W. Is our battery off?
B. (Very indistinct — unintelligible.)

W. That was very indistinct. Put on our battery.

[Original battery replaced.]

B. We may congratulate ourselves upon a great success.
W. Both batteries are on now. (Another sentence heard indistinctly.)

B. We may congratulate ourselves on our great success.
W. We deserve success. Both batteries are on now.

B. Repeat the last sentence.

W. Both batteries are on now.

B. I understood that before, but thought you said something else.

W. Remove their battery, please.

B. All right; our battery is the only one on now.

W. I have put battery cells on here.

B. How many cells have you there?

W. S-i-x—six.

B. Please whisper something to me.

W. Sound of the whisper clearly audible, but the utterances unintelligible.

B. I could hear you whispering, but could not understand what you said.

W. Perhaps we have got the batteries opposed to one another. Had you not better reverse your battery and see what the matter is, or rather what the effect is?

B. I will try the effect of reversing my battery.

B. Repeat the last sentence.

W. Both batteries are on now.

B. I understood that before, but thought you said something else.

W. Reverse your battery, please.

B. All right; our battery is the only one on now.

W. I have six Daniell cells on here.

B. How many cells have you on there?

W. S-i-x—six.

B. Please whisper something to me.

W. Now I am whispering.

B. I could hear you whispering, but could not understand what you said.

W. Perhaps we have got the batteries opposed to one another. Had you not better reverse yours, and see what the effect is?

B. I will try the effect of reversing my battery.

[Battery reversed.]

B. Is this any better?

W. That sentence was accompanied by that curious crackling sound.

B. Yes; I hear it, too.

B. What time is it by your watch?

B. Is this any better?

W. Much fainter, accompanied by that curious bubbling sound.

. . . . . .
. . . . . .
. . . . . .

[Battery again reversed.]

W. What are you doing? I have not heard anything except . . . for quite a while.

B. I asked you what time it was by your watch. Perhaps you hear me better now, because I have reversed the battery again.

W. My battery is now cut out.

B. Don't you think we better go home now?

W. Yes; but why does your talking come out so much fainter now?

W. What are you doing? I haven't heard anything except that bubbling sound for quite a while.

B. I asked you . . . . .
. . . . . .
. . because I . . . . .
. . . . . .

W. My battery is now cut out.

B. Do you think we had better go home now?

W. Yes; but why does your talking come out so much fainter now?

[Mr. Bell here placed the magnet of the telephone nearer to the membrane.]

B. Because I had moved the magnet further away from the membrane.

W. That was very much more distinct.

B. Will you try to understand a long sentence, if I speak right on?

W. I will.

B. A few minutes ago I heard a fire engine pass by the door. I don't know where the fire is, but the number of the box is 196.

W. The time by my watch is five minutes past ten. Had I not better go into Boston?

B. Yes; I think it is time to stop now.

W. Shall I go to Exeter Place?

B. Yes; but look in here on your way, in case I have not gone.

W. Let us talk conversationally, without noting.

B. Because I moved the magnet further away from the membrane.

W. That was very much more distinct.

B. Will you try to understand a longer sentence, if I speak right on?

W. I will.

B. A few minutes ago I heard a fire engine go past the door. I don't know where the fire is, but the number of the box is 196.

W. The time by my watch is five minutes past ten. Had I not better go into Boston?

B. Yes; I think it is time to stop now.

W. Shall I go to Exeter Place?

B. Yes; but look in here on your way, in case I have not gone.

W. Let us talk conversationally, without noting.

Conversation was then carried on for about half an hour with the utmost freedom, and the experiment closed.

Boston Evening Transcript, Oct. 19, 1876: —

"*Telephony* , . . The registry of sounds by telegraph has now been carried to such a point that the delicate variations involved in the articulation of human speech are transmitted with such unerring accuracy and distinctness that one may talk with another through the telegraph as though face to face.

"The leading scientific men of the world gathered at Philadelphia last summer saw the fact accomplished on a small experimental scale. Sir W. Thomson was so impressed that in his opening address as president of the British Association, he described it at some length, and pronounced it the greatest by far of all the marvels of the electric telegraph. Ten days ago the test was repeated over an actual out-of-door telegraph between this city and Cambridge. The entire success of this experiment marks, for all that we can see, a revolution and advance in the world's progress worthy to rank with the practical completion of the first printing telegraph in New York city, about forty years ago, and with the laying of the great ocean cables twenty years ago.

"The operation of this new and startling development of telegraphic mechanism is thus described by Professor Thomson, in the address referred to: —

"'All this my own ear heard spoken to me with unmistakable distinctness by the thin, circular disk armature of just such another little electro-magnet as this which I hold in my hand. The words were shouted with a clear and loud voice by my colleague judge, Professor Watson, at the far end of the line, holding his mouth close to a stretched membrane, such as you see before you here, carrying a little piece of soft iron, which was thus made to perform, in the neighborhood of an electro-magnet in circuit with the line, motions proportional to the sonorific motions of the air.' . . .

"We give in another column the interesting account of the practical exemplification of the invention between Boston and Cambridge. The inventor, Mr. Graham Bell, is a young Edinburgh scientist, formerly of Montreal, but later of this city, and a naturalized citizen of the United States."

New York *Tribune*, Monday, Oct. 23, 1876: —

"The experiments which Professor A. Graham Bell has been recently making, relative to the transmission of speech by wire, have been quite successful. Two operators were stationed two miles apart, one in Boston and the other in Cambridge. The battery ordinarily used was replaced by one of ten carbon elements. At first the sounds were indistinct, but soon they grew clear and intelligible. The operators carried on a long conversation, and on subsequently comparing their records ascertained that the tones had been transmitted with perfect accuracy."

Editorial in the New York *Tribune*, Nov. 9, 1876:—

"The Centennial Exhibition has afforded the opportunity to bring into public view many inventions and improvements which otherwise would only have been known to the smaller circles that may find them of service. . . . The telephone is a new instrument of electrical science, more likely than some of the rest to find immediate use. It operates by transmitting the current through a tuning fork. The fork will only vibrate a given number of times in a second. A message can be sent through it by the usual Morse code, there being no apparent interference between the tuning-fork vibrations and the message. But at the other end of the line the message can be taken off through a tuning-fork in unison with the first. Consequently, if a tuning-fork of different pitch is interposed at each of several stations served by one wire, and the messages are sent through forks of corresponding pitch from the head office, the message to one station will not be repeated at the others during transmission.

"Sir William Thomson, at the Glasgow meeting of the British Association for the Advancement of Science, gave foreign notoriety to another of the Centennial exhibits that has attracted great attention from the judges of the Group to which it belongs. It is a curious device, that might fairly find place in the magic of Arabian tales. A

membrane is stretched over the end of a short speaking trumpet. The membrane carries a small piece of metal which is, so to speak, the armature of a magnet. The magnet forms part of a telegraph circuit, through which a current is passing. To send a message, it is only needful to talk loudly into the trumpet.

"The message is received by a similar trumpet with membrane and armature at the other end of the line; and that trumpet being placed to the ear repeats the sound like an echo. Don Pedro was with the scientific people who tested this instrument on one occasion; so accurately did it reproduce sounds that each member of the party was in turn recognized by peculiarities in voice or accent. The final test was the reading of a paragraph from the news columns of the *Tribune*. Of what use is such an invention? Well, there may be occasions of state when it is necessary for officials who are far apart to talk with each other without the interference of an operator. Or some lover may wish to pop the question directly into the ear of a lady, and hear for himself her reply, though miles away; it is not for us to guess how courtships will be carried on in the twentieth century. It is said that the human voice has been conveyed by this contrivance over a circuit of sixty miles. Music can be readily transmitted. Think of serenading by telegraph!"

The Boston *Post*, Nov. 27, 1876:—

"The experiments in electric telephony which Professor A. Graham Bell has been conducting for several years past have resulted in the development of an apparatus by means of which the human voice, as ordinarily used in speaking, can be transmitted with certainty and ease to an indefinite distance,— assuredly hundreds of miles.

"The latest experiments with the telephone were made yesterday over the wires of the Eastern Railroad, that day being selected because the trials would not then be interrupted by the ordinary business of the line. Professor Bell, President Rockwell, of the Eastern Road, and wife, Miss Stearns, Mr. Morrison, and Mr. Hubbard, besides two telegraph operators, were the occupants of the Boston office. The instruments were arranged for about a twenty-mile test; consequently, Salem, about sixteen miles away, was the point at which the second telephone was fixed. Mr. Thomas A. Watson, assisted by the Salem operator, was in charge there. All those at the Boston end of the line held free and easy conversation with the Salem office, even a whisper or a loud breath being distinctly heard at one end when given at the other."

Evening Star, Washington, Jan. 20, 1877: —

"*Bell's Telephone.* At a meeting of the Washington Philosophical Society, on the evening of the 13th January, Mr. Bell, the inventor, gave to the members a description of the construction and

operation of his most admirable and wonderful invention, *and exhibited it in operation.*"

Boston *Daily Advertiser*, Jan. 22, 1877 : —

"The most important of the tests made recently by Professor A. Graham Bell, in the practical development of telephony, is dispensing with the use of the battery entirely, so that now all that is required to communicate between the most distant places is simply a line of wire and the telephones.

"Yesterday morning successful experiments were made between Boston and Salem, on the Eastern Railroad wire. At the Boston end were Professor Bell, Mr. Nutting, the operator, Mr. E. H. Foster, Mr. William Auld, and Mr. J. B. Parker; and at the Salem end, Mr. T. A. Watson, who is associated with Mr. Bell, and the lady operator.

"Recently two Japanese gentlemen conversed in their own language through the telephone, and had no difficulty in understanding all that they said. An experiment has been made in overcoming an artificial resistance greater than the Atlantic cable, and there is no doubt but that it will be possible to talk across the Atlantic."

The Boston *Evening Transcript*, Feb 1, 1877 : —

"At noon, yesterday, a distinguished party of gentlemen were assembled at the office of the Boston Rubber Shoe Company, on Congress street, in order to witness a series of experiments performed on the telephone between the inventor, Professor A. Graham Bell, here, and his associate, Mr. Thomas A. Watson, at the residence of Mr. Converse, at Malden, about six miles distant.

"Professor Bell had been invited by some of our most prominent citizens to give a practical demonstration of the most recent developments of an invention which, in accordance with its name, has already sounded far and wide the fame of the telephone. The experiments yesterday were as follows : —

"Telephones having been connected with the private telegraphic line of the Boston Rubber Shoe Company, and the operators at either end having taken up their stations, conversation was at once commenced. Stationed at the Boston end of the wire, Professor Bell requested Mr. Watson to speak in loud tones, with a view of enabling the entire company at once to distinguish the sounds.

"This was so successful, that a smile of mingled pleasure and surprise played on the features of those present. That it, however, might not be supposed that loud speaking was essential to intelligibility, Mr. Bell explained that soft tones could be heard across the wires even more distinctly than loud utterances, even a whisper being audible. In confirmation of this statement, Mr. Watson commenced speaking in turn to each member of the company, and after the efficiency of this method had been proved to the satisfaction of

all, he took up a newspaper and informed the assemblage that gold had closed the previous evening at New York at 105⅝.

"As there was quite a number of business men present, the effect that this practical demonstration of the value of the telephone produced can scarcely be exaggerated. Other passages from the daily journals were then given, and by this time the desire for conversation having become general, Mr. Watson was plied with questions, such as, Is it thawing or freezing at Malden? Who is to be the next President? etc., etc. It was remarkable that Mr. Watson was able to distinguish between the voices at the Boston end, he calling at least one gentleman by name as soon as the latter commenced speaking.

"This went on for some time, until a lady at the Malden end sent the company an invitation to lunch per telephone, and an appropriate response was made by the same medium.

"At length the company were requested to remain quiet while the lady at the other end conveyed to them the sweet strains of music. The assemblage thereupon listened with rapt attention while a young lady commenced singing 'The Last Rose of Summer.' The effect was simply charming. Possessing, as the fair cantatrice does, a voice of exquisite sweetness, the sounds penetrated into the Boston end of the telephone with a distinctness equal to that attainable in the more distant parts of a large concert room, and a unanimous vote of thanks was sent by the handy little instrument which had procured for the assemblage so agreeable an hour.

"Among those present were electricians and gentlemen occupying prominent positions on our Western railroads, and one and all expressed the conviction that the telephone was destined to achieve the greatest possible results. Let us hope that the day is fast approaching when every man will be in a position to turn on the electricity in his house with the same facility with which he now turns on the water or the gas.

C. H. H."

Boston *Globe* of Feb. 13, 1877:—

"We have the pleasure of presenting to our readers this morning the first despatch ever sent to a newspaper by the newly invented telephone, Professor A. Graham Bell's system of transmitting sound by telegraph. The despatch was sent from Salem, where Professor Bell lectured last evening, our active representative in that city having secured the exclusive privilege of the instrument for that purpose. The message was received in this city by another representative of the *Globe*, who could readily recognize the voice at the other end.

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"SENT BY TELEPHONE. — THE FIRST NEWSPAPER DESPATCH SENT BY A HUMAN VOICE OVER THE WIRES. — TO THE DAILY GLOBE, FROM SALEM. — PROFESSOR GRAHAM BELL EXPLAINS HIS VALUABLE INVENTION. — AN ENTHUSIASTIC AUDIENCE. — HOW THE CAPACITY OF THE TELEPHONE WAS TESTED.

"(*Special despatch by telephone to the Boston Globe.*)

"SALEM, Feb. 12, 10.55 P. M. — Professor A. Graham Bell, the inventor of that wonderful instrument, the telephone, which has caused so much interest in the scientific world, and which is now becoming so popularly known, lectured on his invention at Lyceum Hall this evening. The lecture was one of a course of the Essex Institute, and about five hundred persons were present.

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"Mr. Watson was then asked to make a speech to the audience. He expressed himself as having more confidence eighteen miles away than if he were present. His speech was as follows: —

"'*Ladies and Gentlemen*, — It gives me great pleasure to be able to address you this evening, although I am in Boston and you in Salem.' This could be heard thirty-five feet distant, — that is, all over the hall, — and brought down the house with applause. A system of questioning was then carried on, and Mr. Watson was asked if he heard the applause. The answer was, 'I was not listening; try again.' The applause was given, and its receipt at once acknowledged in Boston. Coughing and singing were then heard, and a variety of questions were then asked from the Salem end, and among them, 'What news from the Electoral Commission?' followed by the distinct answer of 'I don't know of any.' But the news came fleeting along that the engineers of the Boston and Maine Railroad had struck. Gen. Cogswell asked if trains were running; the answer was clear and distinct that they were not at 5.30 o'clock. Professor Bell introduced the Rev. E. C. Bolles, who said, 'I shake hands with you cordially in imagination twenty miles away.' The Rev. E. S. Atwood asked, 'Does it rain?' 'It does not in Boston,' was Mr. Watson's answer. Professor Gage, the electrician, then spoke through the telephone, endeavoring to have his voice recognized. This could not be done, as Mr. Watson was not familiar with the voice. Mr. Shaje Zsawa was recognized, Mr. Watson being perfectly familiar with his tones. One of the assistants in Boston then said that 'Hold the Fort' would be sung in Boston, and the tune which followed was readily recognized. Professor Bell closed his lecture by briefly stating the practical uses to which he was confident the telephone could be applied. Hearty applause was afforded the lecturer as he finished, and people flocked about the stage in large numbers to more closely examine the wonderful instrument that had

placed them in audible communication with people nearly twenty miles away.

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"This special by telephone to the *Globe* has been transmitted in the presence of about twenty, who have thus been witnesses to a feat never before attempted; that is, the sending of a newspaper dispatch over the space of eighteen miles by the human voice; and all this wonder being accomplished in a time not much longer than would be consumed in an ordinary conversation between two people in the same room.

H. M. B.

"THE SCENE AT THE BOSTON END.

"The instrument which transmitted the wonderful voice-message to the listening ears in this city was placed in a little room in Exeter Place, where were assembled Prof. Watson, Benjamin Bridden, the electrician, Prof. E. B. Warman, and Mr. A. B. Fletcher, representative of the *Globe*. The experiment was certainly a great success. The conversation with the friends eighteen miles away was carried on in ordinary tones of voice. The *Globe* representative in Boston very easily recognized the voice of the transmitter of the dispatch in Salem, and very distinctly heard the applause which was given in the Essex Institute Hall. It was a very noteworthy occasion, certainly; and the complete success attained led to the discussion of many plans for the further practical utilization of the telephone, which sends its first newspaper dispatch to the *Globe* readers for their delectation and wonder this morning."

Boston *Daily Globe*, Feb. 15, 1877: —

"THE TELEPHONE. — SOMETHING ABOUT THE CONSTRUCTION AND WORKING OF PROF. BELL'S WONDERFUL INVENTION.

"As the telephone, the new invention of Prof. A. Graham Bell, is but little understood, the following reprint of a description and explanation of the instrument may not be amiss: —

"'The telephone in its present form consists of a powerful, compound, permanent magnet, to the poles of which are attached ordinary telegraph coils of insulated wire. In front of the poles, surrounded by these coils of wire, is placed a diaphragm of iron. A mouth-piece to converge the sound upon this diaphragm substantially completes the arrangement. The motion of steel or iron in front of the poles of a magnet creates a current of electricity in coils surrounding the poles of the magnet, and the duration of this current of electricity coincides with the duration of the motion of the steel or iron moved or vibrated in the proximity of the magnet. When the human voice causes the diaphragm to vibrate, electrical undulations are induced in the coils environing the magnets precisely analogous

to the undulations of the air produced by that voice. These coils are connected with the line wire, which may be of any length, provided the insulation be good. The undulations which are induced in these coils travel through the line wire, and passing through the coils of an instrument of precisely similar construction at the distant station, are again resolved into air undulations by the diaphragm of this instrument.

"It was by this wonderfully simple instrument that the three quarters of a column report of Professor Bell's lecture was transmitted from Salem to the *Globe* by the voice on Monday evening. All who saw the working of the instrument were astounded at the results obtained."

Salem *Observer*, Feb. 17, 1877 :—

"THE TELEPHONE. — The illustrated lecture upon telephony, by Professor A. Graham Bell, was exceedingly interesting. The results exhibited were indeed amazing; nearly every experiment was successful. . . .

"On Monday evening Mr. Watson, who was in the Boston office, 'wired' several tests to the audience of five hundred who were assembled in Lyceum Hall. He conversed with Professor Bell freely, the latter asking questions in an ordinary tone of voice, with distinct articulation, and the answers immediately returning and having a sort of muffled sound. Mr. Watson addressed some words to the audience in Salem, which were distinctly heard, and the applause which followed was heard by him in Boston. He sang 'Auld Lang Syne' and other pieces, and played upon a reed organ, all the sounds of which were duly delivered at the Salem end of the wire. The person in Boston was also heard to cough and to laugh. During the evening Rev. Dr. Bolles, Rev. Mr. Atwood, Professor Gage, General Cogswell, a gentleman from Japan, and a lady (Miss Loring), all spoke successfully through the telephone. A full report of the meeting was sent to the *Globe* by telephone from its correspondent, Mr. Batchelder.

"The apparatus by which this astonishing result is secured is wonderfully simple; only a telegraphic wire, a horseshoe magnet, two helices, and a vibrating disk at each end. The audience see only a mahogany box upon the table, of the appearance of an ordinary photographer's camera. The tube in the end is used in this case to speak into and to hear out of. Within the box is a horseshoe magnet. Opposite each arm of the magnet is a helix of the usual construction.

"One end of the wire among the helices is connected with the ground, and the other with Boston, or the place in operating connection. Set up against the helices, within a sixteenth of an inch, is a sheet of thin polished iron, upon which the voice of the operator impinges when speaking. The magnet induces an electrical current

in the telegraphic wire. The vibrating disk imparts pulsations to this electrical current corresponding to the sounds, which are conveyed to Boston, and reproduce themselves upon the vibrating disk there with exactness of tone and articulation. The little four inches of iron utters the whole gamut of the human voice. This is indeed wonderful, — the greatest achievement of modern science. Another exhibition of the telephone is to be given."

New York *Sun*, Feb. 20, 1877: —

PROF. BELL'S TELEPHONE. — THE HUMAN VOICE CARRIED A HUNDRED AND FORTY MILES. — MARVELLOUS STORIES ABOUT THE LATEST ACHIEVEMENT OF SCIENCE. — MUSIC IN SALEM AND APPLAUSE IN BOSTON. — THE CONSTRUCTION AND CAPABILITIES OF THE INSTRUMENT DESCRIBED.

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"The honor of having received the first newspaper dispatch ever sent by means of the telephone belongs to the Boston *Globe*. A report of a lecture by Professor Bell, in Salem, was transmitted verbally to it last Monday night. This lecture was about the telephone, and in the course of the evening a series of remarkable experiments was made in the presence of the audience. Songs and brief speeches were sent from Boston, and the applause which greeted their reception in Salem was distinctly heard in Boston. Imagine sitting in a hall and hearing a man, eighteen miles away, sing 'Hold the Fort.'

"'I haven't the slightest doubt,' Mr. Watson said to-day, 'that in a few months things will be so that a man can make a lecture here in Boston, and be heard by an audience in any part of the country.'

"'Do you expect that the telephone will entirely supersede the present system of telegraphing?' I asked.

"'Yes; we expect it will, eventually. A company is now forming for the purpose of manufacturing and introducing the instrument. In time it can't fail to replace the old dot and line alphabet system entirely. We expect, at first, it will be used mostly on private lines and for city business. It will probably take the place of the present district telegraph companies and the like, as it will be especially convenient for that class of business.'

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"The wonderful little instrument, of whose future value to civilization the inventor is so sanguine, consists of a powerful compound permanent magnet, to the poles of which are attached ordinary telegraph coils of insulated wire. In front of the poles, surrounded by these coils of wire, is a diaphragm of iron. A mouthpiece, whose function is to converge the sound upon this diaphragm, substantially completes the arrangement. The operation of the instrument is thus described by Professor Bell: The motion of steel or iron in front of the poles of a magnet creates a current of electricity in coils

surrounding the poles of the magnet, and the duration of this current of electricity coincides with the duration of the motion of the steel or iron moved or vibrated in the proximity of the magnet. When the human voice causes the diaphragm to vibrate, electrical undulations are induced in the coils around the magnets precisely similar to the undulations of the air produced by the voice. The coils are connected with the line wire, and the undulations induced in them travel through the wire, and passing through the coils of another instrument of similar construction at the other end of the line, are again resolved into air undulations by the diaphragm of this instrument. The voltaic battery is entirely dispensed with. The line wire may be of any given length, provided the insulation be good. Professor Bell further says that soft tones can be heard across the wires even more distinctly than loud utterances, even a whisper being audible."

Boston *Daily Globe*, Feb. 24, 1877 : —

"*Special despatch by Telephone to the* BOSTON GLOBE.

"SALEM, Friday, Feb. 23, 10.20 P. M. — Lyceum Hall has been crowded this evening with an audience of five hundred, which had assembled to hear Professor A. Graham Bell's interesting lecture on his wonderful invention, the telephone, and the results obtained by the evening's exhibition were certainly most astonishing. This was the second public exhibition of the new invention and its practical uses, and Salem has been fortunate indeed in having both given before her citizens. This second lecture and exhibition was given in response to an invitation to Professor Bell by a number of scientific gentlemen and prominent citizens, and the audience was one which only a rare and notable occasion can draw together in Salem. Among the more prominent people in the audience were the Hon. George B. Loring, Judge Endicott, of the Supreme Court, Professor D. B. Hagar, of the State Normal School, Dr. J. R. Nichols, of Haverhill, editor of the Boston *Journal of Chemistry*, Judge Osgood, Mayor Oliver, Aldermen Dayton and Stone, Professor John Robinson, ex-Mayor Williams, Dr. Henry Wheatland, President of the Essex Institute, the Rev. Messrs. Arey, Dean, and Atwood. John W. Perkins, master of the Salem High School, General William Cogswell, J. S. Packard, Esq., and many other prominent citizens. The experiments were similar to those given at the former lecture, and were eminently successful, receiving hearty applause. Professor Thomas A. Watson, Professor Bell's assistant, transmitted several messages from the Boston end of the telephonic wire.

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"The company at the Boston end of the telephonic wire between Boston and Salem was quite as numerous as Professor Bell's laboratory could well accommodate. It is a little room at the end of Exeter Place, up three flights of stairs, with the various instruments

of the telephonic apparatus to be seen on every hand. On one of the tables were the models on which Professor Bell worked out the telephone as it now exists; and they form an interesting study. Books, letters and papers, all pertaining in more or less degree to the science of electricity, were arranged about the room, which is plainly and tastefully furnished. Occupying the post of duty near the working instrument was Professor Thomas A. Watson, Mr. B. F. Bridden having charge of the working of the electric apparatus, with two young lads as assistants. The company present included Mr. D. P. Richards, who has been one of Professor Bell's co-workers, the Hon. Charles Levi Woodbury, John C. Hoadley, of Lawrence, Dr. Henry I. Bowditch, Dr. C. J. Blake, Mr. W. A. Hovey, and Mr. C. E. Hurd, of the *Transcript*, three gentlemen from one of Dr. Tourjée's Tabernacle choirs, a cornet player, and an artist who was illustrating the scene for the *Scientific American*, besides reporters from various city papers.

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"THE GLOBE despatch then came, followed by another press message, giving merely the news furnished by THE GLOBE about the telephone a week ago. Then 'Yankee Doodle' and 'Auld Lang Syne' were sung by Professor Bell, and distinctly heard in every tone by all in the room; and at 10.30 the conference came to an end."

The Providence *Press*, Feb. 24, 1877: —

"We willingly surrender space to-day to the somewhat enthusiastic report by a member of our editorial staff who was invited to witness the experiments with the telephone last night at Salem. The importance of the invention promises to be such as to make all obtainable knowledge of it valuable, and we do not remember to have yet seen any so detailed and intelligible description of its workings as our representative furnishes.

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"HOW THE THING IS DONE,

is, of course, the practical reader's demand. It is done by a magnificent effort of genius, making itself felt with common tools. It is simplicity embodied and almost made personal. There is not even a battery to send an electric current along the line, for the affair is sufficient unto itself within its six by twelve inch dimensions, asking nothing of existing telegraphy but the wires it has strung. The principle is the familiar one that a plate of iron presented to a coil of insulated wire on the end of a magnet causes an electric current to traverse the magnet, provided the circuit is complete. Professor Bell, therefore, takes a horseshoe magnet, places on each of its ends a nearly flat spiral wire, and just in front of the points of the spirals, an infinitesimal distance away, sets up his plate of iron.

To complete this circuit, he connects one arm of the magnet with the earth, by means of the gas pipes, and the other communicating wire runs out from the other arm to wherever the other operator may be stationed, with a similar earth connection on the magnet at his end."

Boston *Journal of Chemistry*, Mar. 1, 1877 : —

"THE TELEPHONE.

"The telephone is the invention of Professor A. Graham Bell, of this city, and has resulted from a course of inductive reasoning, growing out of a careful study of the philosophy of sound, as related to wave motions in air, and in metals when induced by electrical excitation. The instrument is exceedingly simple and inexpensive, and easily understood. It consists in attaching to the terminals of the ordinary telegraph wires, between any two points, powerful compound magnets, with coils of wire connected. In front of the pole, surrounded by these coils of wire, is placed a diaphragm of iron. A mouth-piece to converge the sound upon the diaphragm, substantially completes the arrangement. When the human voice causes the diaphragm to vibrate, closing and breaking the circuit with each vibration, electrical undulations are induced in the coils, precisely analogous to the undulations of the air produced by that voice. These coils are connected with the line wire, which may be of any length, provided the insulation be good. The undulations induced in these coils travel through the line wire, and, passing through the coils of an instrument of precisely similar construction at the distant station, are again resolved into air undulations by the diaphragm of this instrument."

The Providence *Journal*, Mar. 15, 1877 : —

"THE LAST GREAT WONDER.

"In the telephone no galvanic battery is used. A permanent steel magnet is surrounded with a coil of insulated wire, and confronted with a disk of sheet iron. When the iron disk vibrates, under the influence of sound, it disturbs the magnetism of the steel magnet before it; and, by a familiar law, every change of magnetism in a magnet excites an electric current in a surrounding coil. The coil is connected with the telegraph wire, and that with the coil around the magnet at the further end of the line, the ground being used for the return circuit. The distant magnet thrills with the electric current so excited, and vibrates the disk in front of it, which, in turn, impresses sound waves on the air."

The Boston *Daily Globe*, April 6, 1877 : —

"PROFESSOR BELL EXHIBITS ITS WONDERFUL WORKINGS TO A PROVIDENCE AUDIENCE. — A SUCCESS DESPITE UNFAVORABLE CONDITIONS.—A SPECIAL TO THE 'GLOBE' BY TELEPHONE.

"Professor A. Graham Bell, the inventor of the telephone, lec-

tured in Providence last evening; and in his little room at the top of No. 5 Exeter Place, Mr. Thomas A. Watson, the electrician, with several members of the press and a number of gentlemen interested in science, were assembled, for the purpose of holding communication with the professor, and demonstrating anew the practical workings of the instrument.

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"The *Globe* reporter remained with Mr. Watson until a late hour; and when the audience in Providence had been dismissed, and all the visitors had left the room in this city, he was repaid for his waiting by receiving the following message from a brother reporter of the *Globe*, who went to Providence especially to send a telephonic despatch: —

"THE EXHIBITION IN PROVIDENCE.

"'*Special to the* GLOBE *by Telephone.*

"'PROVIDENCE, R. I., April 5.

"'The bad weather prevented the exhibition from being as effective as usual; still, the audience which crowded Music Hall, and represented the best society of the city, had conclusive proof of the value of the invention. The transmission of musical sounds from the reed organ in Boston, giving "Music in Air," and other familiar tunes, was admirably perfect, and was heard distinctly all over the hall. The exhibition of singing was fairly successful; and Mr. Reeves's cornet solo, "Yankee Doodle," played at the request of one of the audience, was recognized very easily. The experiment of brass-band playing was not very successful. A conversation carried on between the Rev. Dr. Behrends here, and Mr. Watson at Boston, on the Rhode Island election, caused much merriment. Governor Lippett introduced Professor Bell, who spoke till after ten o'clock, and remained in the hall an hour after, exhibiting the telephone to a curious crowd. An effort will be made to have the lecture repeated, when, it is hoped, circumstances will be more favorable for the working of Professor Bell's invention.'

"[NOTE. — On account of damage to the wires it was impossible to send as full a despatch as was intended; but, fortunately, the accident did not happen until after the lecture had been delivered, and Providence people had been satisfied of the success of the invention.]"

Providence *Daily Journal*, April 6, 1877: —

"PROFESSOR BELL'S LECTURE ON THE TELEPHONE.

"Music Hall was filled last evening, notwithstanding the storm, by one of our best audiences, to witness the first public exhibition of the speaking telephone in this city.

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"Professor Bell stated that in vocal utterance it is best to remove

the battery, and use nothing between the telephonic instruments in Boston and Providence. The Boston office was then telegraphed to cut out the battery. While waiting for this to be done, Professor Bell explained in a few words the structure of his instrument and its history.

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"Mr. Watson next sung 'Hold the Fort,' which was switched on to the different telephones. Mr. Watson then repeated a sentence, which was switched on to the telephones and generally heard. Rev. Mr. Behrends then interviewed Mr. Watson, asking him if it was stormy in Boston, also 'What time is it?' and 'Have you heard the news from Rhode Island?' Mr. Watson had not. Mr. Behrends informed him that we had an election yesterday, and 'Did you hear who was elected?' Yes, Mr. Watson had read it. 'What is the news in Boston?' Answer, 'I have not heard any.' 'Good night, Mr. Watson,' closed the conference.

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"The mysterious little box at Professor Bell's lecture contains an apparatus almost elementary in its simplicity, which answers the double purpose of transmitting and receiving sounds. It may be divided into two parts, the artificial ear and the magneto-electric transmitter. The artificial ear may be likened to a grocer's sugar funnel, of tin or other metal (having a tube of about two inches diameter), the large, flaring end of which has been sealed with a circular disk of thin sheet iron. This disk is the tympanum of the artificial ear. The two-inch tube is the part which projects from the box into which you talk, and at which you listen for a reply. Inside the box there is a fixed U-shaped steel magnet, whose poles very nearly approach the sheet-iron disk, keeping it in a state of tension by virtue of magnetic attraction. Around the arms of the U magnet, near its poles, are bobbins of fine insulated copper wire, which communicate together, and one of the free ends of which connects with the telegraph wire outside, and the other with the ground, for the return current. For certain reasons it is thought better, in practice, to attach small, sort iron cylinders, on which the bobbins are placed, to the poles of the fixed magnet; and the ends of these cylinders then take the place of the poles of the magnet, in close proximity to the iron disk or tympanum. This is virtually the whole apparatus. When a word is whispered into the two-inch auditory tube it causes the iron tympanum to vibrate. This disturbs the magnetism of the fixed magnet, and of its soft iron cylindrical poles. This disturbance, in its turn, induces electrical currents in the coils of fine wire and in the telegraph wire outside. At the distant station these processes are then taken up in reverse order. The induced currents, passing from the telegraph wire through the coils of the receiving instrument, disturb the magnet-

ism of the fixed magnet there, and that sets the disk in front of it in vibration, which communicates in turn the same sound undulations to the air which originated this curious series of transformations. In other words, the persons listening at the distant disk hear the same words, accents, tones, which were confided to the disk at the near station. It will be observed that the sound waves are converted first into mechanical vibrations of the disk, then into magnetic vibrations, then into electric currents, then back into magnetic vibrations, then into vibrations of the distant disk, and lastly into sound vibrations again, — and that these transmutations of the original sound waves between the two disks require four jumps through air spaces."

New York *Tribune*, May 12, 1877 : —

"An exhibition of the speaking telephone was given last night at the St. Denis Hotel, in this city. An invitation to exhibit the instrument here had been tendered to Professor A. Graham Bell by Professor F. A. P. Barnard, Dr. Howard Crosby, Professor Henry Morton, and two or three dozen other gentlemen eminent in the learned profession, or connected with the telegraph. Before beginning his proposed course of lectures, Professor Bell invited a few of his scientific friends to be present at an informal exhibition, to show the power of the instruments. About fifty gentlemen were gathered in one of the parlors of St. Denis Hotel last evening. Among those present were President Barnard, Professor O. N. Rood, and Professor J. S. Newbury, of Columbia College ; the Rev. Dr. Armitage ; General Eckert, President of the Atlantic and Pacific, and the Hon. T. N. Gibbs, President of the Domestic Telegraph Company ; Professor Peet, of the Deaf and Dumb Asylum ; Eastman Johnson, General Gaylord, S. A. Bunce, R. H. McCurdy, F. O. Evans, and other well-known citizens. There was some delay about the proceedings, which was afterwards explained.

"Professor Barnard introduced Professor Bell to the audience, having become acquainted with the instrument and the inventor at Philadelphia. Professor Barnard stated that of all the instruments of precision and research, etc., which the Group of Centennial judges, of which he was chairman, was called upon to examine, there was none that occasioned greater interest or that they regarded as of higher novelty and importance than the speaking telephone of Professor A. Graham Bell. In introducing Professor Bell to the audience, Professor Barnard said that he did so with the conviction that the name of the inventor of the telephone would be handed down to posterity, with a permanent claim on the gratitude and remembrance of mankind. Professor Bell expressed himself as surprised at the size and importance of the gathering. He had at first expected a small number of his friends, and had arranged to exhibit his telephone merely by placing one of the instruments in one room, and another in another room, in the hotel, connecting them by wires.

But at a late hour he had determined upon a more complete exhibition of the character of the instrument, and had therefore sent his assistant, Mr. Gower, to Brooklyn, and hoped before long to hear that Mr. Gower had arrived somewhere in that city, and to hear it from Mr. Gower through the telephone. While Professor Bell was speaking, a sound was heard from the instrument; he placed his ear against it, and after listening for a moment, said to the audience: 'It is all right. Mr. Gower has been in search of a cornet player, and thinks he will have one to play a tune for us.' Professor Bell then carried on a brief conversation with Mr. Gower, finally desiring the latter to be in readiness after a short interval, in which Professor Bell proposed to explain some features of the instrument to his audience.

"Professor Bell mentioned many of the facts with which our readers are already familiar, as to the construction and character of the instrument. When a magnet approaches a bar of iron, it generates a current or a change of electrical condition in the iron; when it is drawn back it generates the converse electricity: *i. e.*, in the one case positive, in the other negative. What Professor Bell had done was to substitute a sheet or plate of iron for the bar, to make that vibrate instead of the magnet, and to keep the magnet stationary. The vibration was communicated to the plate in front of the poles of the magnet by the waves of sound striking on the plate. These differences of positive and negative electricity, transmitted through the wire, caused a magnet at the other end of the wire to attract or repel a precisely similar iron plate; and the vibrations of that communicated to the air, were sounds precisely corresponding to those presented at the first plate. He has tested it on two hundred and fifty-eight miles of wire between New York and Boston. He commenced by understanding it; now he does not understand it.

"The vibration was supposed to be like that of a membrane, such as is that of the drum of the ear. But we all know that such vibration can be readily dampened by fastening upon the membrane something to stiffen it.

"There was no such result in the telephone when a wooden ring was screwed to the plate; or when the plate itself was made of extraordinary thickness, the vibration is molecular. The curious sounds heard in the telephone were described; some of them had been ascertained to proceed from earth currents. The instrument was more sensitive than a galvanometer to ascertain imperfections in the wire, or imperfect connections.

"The cornet player at last arrived. He was borrowed for a brief period from the orchestra of a neighboring theatre. He played two tunes, the latter one being very distinctly heard. When the note happened to strike the fundamental note of the telephone box, it sounded abnormally loud; otherwise it was fairly rendered. The

voice in Professor Bell's instrument sounds very much as though it had come through a very long speaking-tube. Some practice is necessary to catch the words uttered, the vibrations giving a sort of confusing rattle. Nevertheless, the success of the transmission is unquestionable.

"After Professor Bell had finished speaking, the different members of the audience listened at the instrument, and some of them conversed with Mr. Gower, who was at the telegraph office, No. 340 Fulton street, Brooklyn. Much laughter was occasioned by Professor Bell getting the word Fulton wrong, after asking Mr. Gower where he was; Professor Bell understood him to say 'Beacon street,' perhaps having Boston in his mind. The proprietors of the St. Denis Hotel invited the visitors to a repast after the exhibition."

New York daily papers preceding Chickering Hall lecture, May 17, 1877: —

NEW YORK, April 7, 1877.

"Professor A. GRAHAM BELL, *Boston University:*

"*Dear Sir*,—The interest excited during the Centennial Exhibition by your experiments with your telephone, holding communications in audible speech with persons many miles away, and the published accounts of your improvements in the wonderful instrument, prompt us to request that you will deliver in our city, on some evening convenient to yourself, a lecture on sound and electricity, with an exhibition of your speaking telephone, showing what can be done by it, and making known its scientific and commercial value.

"Very truly, etc.,

"F. A. P. BARNARD [*President Columbia College*].
HOWARD CROSBY [*Chancellor of New York University*].
HENRY MORTON [*Stevens Scientific School*].
E. L. YOUMANS [*Ed. Popular Science Monthly*].
CYRUS W. FIELD [*Atlantic Cable*].
THOS. T. ECKERT [*Pres. Atlantic and Pacific Tel. Co.*].
A. M. MAYER [*Stevens Scientific School*].
WILLIAM ORTON [*Pres. Western Union Tel. Co.*].
J. S. NEWBERRY [*School of Mines, Columbia College*].
C. T. CHANDLER [*Prof. Chemistry, College Phys. and Surgeons*].
H. D. NOYES [*Prof. Aural Surgery, Bellevue College*].
JNO. W. DRAPER [*Prof. Chemistry, New York University*]."

Boston daily papers preceding Music Hall lectures of May, 1877: —

"BOSTON, April 20, 1877.

"Professor ALEXANDER GRAHAM BELL:

"*Sir*, — The undersigned, having followed with great interest the accounts of your discoveries and inventions in connection with the electric telephone, which have from time to time appeared in the

newspapers, and confident that the general public of the city in which your researches have been made will be glad to witness a practical exhibition of your telephone under your direction, respectfully request you to gratify this desire of your fellow-citizens at such time and place as may be most convenient to you.

"Benjamin Pierce [*Prof. Mathematics, Harvard College*].
Joseph Lovering [*Prof. Physics, Harvard College*].
E. N. Horsford [*formerly Rumford Prof., Lawrence S. School*].
Henry W. Longfellow [*Cambridge*].
Geo. B. Emerson [*Boston*].
O. W. Holmes [*Boston*].
Charles W. Eliot [*Pres. University at Cambridge*].
Alexander H. Rice [*Governor of Massachusetts*].
Nehemiah Gibson [*Boston*].
Frederick O. Prince [*afterwards Mayor of Boston*].
William F. Warren [*Cambridge*].
John D. Runkle [*Mass. Inst. Technology and Naut. Al.*].
C. F. Adams [*Quincy*].
Wolcott Gibbs [*Prof. Lawrence Scientific School*].
Edward C. Pickering [*Prof. Physics Mass. Inst. Tech., now Director of the Observatory at Cambridge*]."

The *Scientific American*, Oct. 6, 1877: —

"THE NEW BELL TELEPHONE.

"The telephone has advanced considerably beyond the status of a 'beautiful scientific toy,' which many hastily pronounced it, and is now in constant use on numerous private lines in New York, Boston, and Providence. Professor Bell recently exhibited it before the British Association at Plymouth, England, where it attracted great attention. It is at present manufactured by the Telephone Company, of New York, Mr. Charles A. Cheever, Manager, 32 Tribune Building, in this city."

The *Popular Scientific Review* [an English publication] for 1877, p. 429: —

"The Telephone.—During the recent session of the British Association at Plymouth, the lion's share of attention was unquestionably given to the telephone. Wherever the instrument was to be exhibited, whether in the physical or in the mathematical sections, or at Mr. Preece's popular evening lecture, there were always crowded audiences, eager to learn something about so novel an apparatus. At the *soirées*, too, the telephone stood above everything else as the centre of attraction, and knots of people were crowded round the instrument, anxious to converse with friends in distant apartments. The interest in this subject culminated on the arrival of Professor Graham Bell, the inventor of the talking telegraph."

A paper by W. H. Preece on the telephone, in the *Philosophical Magazine* for April, 1878, beginning as follows:—

"The introduction of the speaking telephone by Alexander Graham Bell has supplied physicists with an instrument of research, as well as with an instrument of practical utility."

Westminster Review, January, 1878 (p. 208): —

"Of all modern inventions connected with the transmission of telegraphic signals, the telephone, devised by Mr. Alexander Graham Bell, has excited the most wide-spread interest and wonder. Wherever Mr. Bell has appeared before the public to give an account of his invention and the researches which have led up to it, crowds have assembled to hear him. Nor is this astonishing; for the telephone professes not only to convey intelligible signals to great distances without the use of a battery, but to transmit in *fac simile* the tones of the human voice, so that a voice shall be as certainly recognized when heard over a distance of a few hundreds of miles as if its owner were speaking in a room by our side. And the telephone does not fall short of its profession. Scientific men have had their wonder and curiosity aroused even more than the unscientific public, since a scientific man appreciates the enormous difficulties to be overcome before such an instrument can be realized. Had any hardy speculator a few years ago proposed a telephone which should act on the principle and be constructed in the form of Mr. Bell's instrument, he would probably have been considered a lunatic." . . .

Chicago *Tribune*: —

[*Report of Gray's Lecture, Feb.* 27, 1877.]

"Another development of the telephone was interesting in a scientific point of view. Prof. Bell, in his investigations, had gone a step beyond composite tones, although they were embraced in it, and developed the transmission of vocal sounds."

New York *Tribune*, April 3, 1877: —

"After the first part of the programme had been executed, Mr. Elisha Gray came forward and addressed the audience. He was aware that great confusion existed in the popular mind as to what this telephone could perform; in particular, it had been confounded with the speaking telephone invented by Prof. A. Graham Bell, of Boston. Prof. Bell, Mr. Gray said, was present in the audience."

Boston *Daily Advertiser*, April 5, 1877: —

"The first telephone line that was ever established has just been constructed between the office of Mr. Charles Williams, electrician, in this city, and his house in Somerville, and a conversation can be carried on with perfect distinctness. Mr. Bell was in New York on Tuesday evening, and conversed readily over the regular wires with

parties in this city. He lectures in Providence this evening on Telephones."

Boston *Post*, Thursday Morning, April 5, 1877 : —

"The telephone has been put into practical use; yesterday a line was opened from the office of Charles Williams, Esq., 109 Court street, to his house in East Somerville. The great value of this invention is thus manifested, for by its uses Mr. Williams is now able to converse with his family when separated from them by fully three miles of distance."

The Boston *Daily Globe*, April 5, 1877 : —

"PERFECTING THE TELEPHONE.

"Professor A. Graham Bell, the inventor of the telephone, had the pleasure of assisting at the opening of the first regular telephone line in the world, a private line between the place of business of a gentleman in this city and his residence in Somerville. The instrument worked admirably, and the enterprising gentleman is very much pleased with his private telephonic wire between town and home. The practical value of Professor Bell's invention is being newly proved every day.

"While the professor was in New York recently, he communicated with his associate in Boston, Mr. Watson, and the telephone transmitted conversation over 280 miles of space with wonderful clearness and distinctness of sound."

The Boston *Herald*, April 5, 1877 : —

"The first telephone line ever established has just been constructed between the office of Mr. Charles Williams, electrician, in this city, and his house in Somerville."

The Boston *Traveller*, April 5, 1877 : —

"The first telephone line ever established has just been constructed between the office of Mr. Charles Williams, in this city, and his house in Somerville."

Journal of the Telegraph, April 16, 1877 : —

"The first regular telephone line has been put in operation between the place of business of Mr. C. Williams, 109 Court Street, Boston, Mass., and his residence in Somerville, a distance of about three miles. Mr. Williams states that it works well, and that 'conversation can be carried on by it nearly as well as if in the same room.'"

The *Daily Graphic*, New York, Wednesday, May 23, 1877 : —

"The telephone is quickly working out a practical application. A Boston company is prepared to furnish telephonic communication between places not over twenty miles apart. The advantages are thus set forth: No skilled operator employed; a little practice makes any one master of the telephone; communication more rapid,

the telephone transmits one or two hundred words per minute; the old telegraph apparatus averages not more than twenty; no expense required in its operation; no battery needed; two telephones connecting two houses may be leased for $20 per year. The company keep the instruments in working order. It must be understood that the rental mentioned above is for the use of the telephonic instrument. A telegraph line, when required, will cost from $100 to $150 per mile."

The Boston *Herald*, May 19, 1877: —

"PRACTICAL USE OF THE TELEPHONE.

"A telephone is to be placed in the City Hall, Cambridge, in the office of the Water Board, to establish communication with the water works at Fresh Pond. A line of wire has been constructed, it being originally intended for the use of the printing telegraph. At the suggestion of Hon. Gardiner G. Hubbard, a telephone is to be substituted, that gentleman guaranteeing that the city shall be subjected to no expense unless the machine proves satisfactory."

Boston *Daily Advertiser*, May 19, 1877: —

"THE FIRST PRACTICAL APPLICATION OF THE TELEPHONE.

"The Water Board of Cambridge has decided to have telephone communication with the water works at Fresh Pond, in order to facilitate the sending of messages. The Board has accepted the offer of Mr. Gardiner G. Hubbard to place the telephone in operation, the city to be at no expense unless the arrangement proves satisfactory. Mr. Hubbard was formerly President of the Board, and feels interested in having Cambridge first to apply the wonderful invention to public service."

Boston Evening Transcript, May 18, 1877: —

"THE TELEPHONE.

"Another successful series of experiments with the telephone was made yesterday afternoon at the rooms of Professor Holmes, electrician, on Washington street. At this place Mr. T. M. Carter played several cornet solos, which were distinctly heard at the rooms of Messrs. Brewster, Bassett & Co., on Congress street, at a branch office on Court street, and in Somerville.

"In response, Mrs. Williams sang several songs in Somerville, which were plainly heard at these points above mentioned in this city; and singing from the Court street office was heard in all the other places.

"Conversation was also carried on between the several points connected with perfect ease."

EVIDENCE FOR COMPLAINANTS IN REPLY.

Evidence taken on behalf of complainants before Samuel Bell, Esq., Special Examiner, at the office of Charles Howson, Esq., No. 119 South Fourth Street, Philadelphia, this eighteenth day of May, 1885.

Present, FURMAN SHEPPARD, Esq., *for Respondents.*
CHARLES HOWSON, Esq., *for Complainants.*

Complainants' counsel offers in evidence, copy, certified by the Commissioner of Patents, of the specification and drawing of Letters Patent of the Kingdom of Great Britain and Ireland, No. 4,765, dated Dec. 9, 1876, sealed May 15, 1877, granted to William Morgan-Brown, for Improvements in "Electric Telephony" &c., a communication from Alexander Graham Bell, of Boston, Massachusetts, United States of America, and which is marked "Complainants' Exhibit, Certified Copy of Bell's English Patent," Samuel Bell, Special Examiner.

COMPLAINANT'S EXHIBIT "CERTIFIED COPY OF BELL'S ENGLISH PATENT," SAMUEL BELL, SPECIAL EXAMINER.

DEPARTMENT OF THE INTERIOR.

UNITED STATES PATENT OFFICE.

To all persons to whom these presents shall come, Greeting: —

This is to certify that the annexed has been carefully compared with the Bound Volumes of the Library of this Office, and is a true copy of the Specification and Drawing of Letters Patent of the United Kingdom of Great Britain and Ireland, No. 4,765, dated Decem-9, 1876, sealed May 15, 1877, granted William Morgan-Brown, for Improvements in Electric Telephony, &c.

In testimony whereof I, M. V. Montgomery, Commissioner of Patents, have caused the Seal of the Patent Office to be affixed this twelfth day of May, in the year of our Lord, one thousand eight hundred and eighty-five, and of the Independence of the United States the one hundred and ninth.

{ Seal of the U. S. Patent Office. }

M. V. MONTGOMERY,
Commissioner.

A.D. 1876, 9th DECEMBER. Nº 4765.

ELECTRIC TELEPHONY.

LETTERS PATENT to William Morgan-Brown, of the firm of Brandon and Morgan-Brown, Engineers and Patent Agents, of 38, Southampton Buildings, London, and 1, Rue Laffitte, Paris, for the invention of "IMPROVEMENTS IN ELECTRIC TELEPHONY (TRANSMITTING OR CAUSING SOUNDS FOR TELEGRAPHING MESSAGES) AND TELEPHONIC APPARATUS." A communication from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology.

Sealed the 15th May 1877, and dated the 9th December 1876.

PROVISIONAL SPECIFICATION left by the said William Morgan-Brown at the Office of the Commissioners of Patents on the 9th December 1876.

WILLIAM MORGAN-BROWN of the firm of Brandon and Morgan-Brown, Engineers and Patent Agents of 38 Southampton Buildings, London, and 1 Rue Laffitte, Paris, "IMPROVEMENTS IN ELECTRIC TELEPHONY (TRANSMITTING OR CAUSING SOUNDS FOR TELEGRAPHING MESSAGES) AND TELEPHONIC APPARATUS."

In all previous systems of telegraphy, messages have been received either by means of chemical changes produced by the action of the electrical current, as in the various forms of automatic and autographical telegraphs, or by means of the mechanical movement of a portion of the receiving instrument operating to produce a visible signal, as in needle telegraphs, a mark upon paper or other material, as in printing telegraphs, or a sound as in the Morse system.

Upon these and all other plans, it has been found difficult if not impossible to distinguish between more than four messages transmitted simultaneously over the same circuit, two in each direction.

This present invention relates to the reproduction by the necessary receiving instruments, of any particular sounds or combination of sounds, through the agency of an electric current, whereby a multiplicity of telegraphic messages may be sent simultaneously over a single circuit in the same or in opposite directions, and received without confusion, and whereby articulate speech may be electrically transmitted.

The first part of the invention relates to the production or transmission of musical notes by means of intermittent impulses of voltaic electricity, and to the utilization of such musical notes as telegraphic signals, whereby two or more telegraphic messages can be sent simultaneously in the same direction, over a single circuit.

The second part of the invention relates to the production or transmission of musical notes by means of intermittent impulses of induced electricity, whereby two or more telegraphic signals or messages can be sent simultaneously over a single circuit, in the same or in opposite directions.

The third part of the invention relates to the production or transmission of musical notes by means of undulatory currents of electricity, one battery being used for the whole circuit, whereby two or more telegraphic signals or messages can be transmitted simultaneously over a single circuit, in the same or in opposite directions.

The fourth part of the invention relates to the electrical production or transmission of sounds of every kind, by means of undulatory currents of electricity, whereby not only musicial sounds but articulate speech can be transmitted over a telegraph line, and two or more messages be simultaneously sent over a single circuit in the same or in opposite directions.

The fifth part of the invention relates to the electrical production or transmission of sounds of every kind, without a battery, by means of undulatory currents of electricity, whereby not only the musical notes but articulate speech can be transmitted over a telegraph line, and two or more messages be sent simultaneously over a single circuit, in the same or in opposite directions.

The sixth part of the invention relates to the automatic reception of signals or messages, by introducing at the receiving end of the line a local circuit containing a vibratory circuit breaker, whereby telephonic signals or messages may be automatically recorded.

The seventh part of the invention relates to the application of electric telephony to autographic telegraphy, whereby characters or marks of any description may be copied in *fac-simile* at the receiving end of the line.

FIRST PLAN.

The first part of the invention, (illustrated in Figures 1 and 2 of sheet 1, and Figures 3, 4, and 5 of Sheet 2) consists of a method of, and apparatus for, transmitting two or more telegraphic messages or signals simultaneously along a single wire, by the employment of transmitting instruments, each of which occasions a succession of electrical impulses differing in rate from the others; and of receiving instruments, each tuned to a pitch at which it will be put in vibration to produce its fundamental note, by one only of the transmitting instruments.

The transmitting instrument T (Figure 1.) consists of an electro-magnet *e*, having a steel spring armature *a*, which is kept in continuous vibration by the action of a local battery *b;* the armature *a*, in the course of its vibration, brings the platinum rivet *r*, alternately into contact with two platinum points *l*, and *m*, one *l*, being placed in a local circuit *b*, s^2, *e*, *l*, *r*, s^3, *b*, and the other *m*, communicating with the line wire W, through the screw cap s^1.

The receiving instrument R, shown in plan in Figure 1, and in elevation in Figure 2, consists of an electro-magnet E, having a coil upon only one of its legs. A steel spring armature A, is firmly clamped by one extremity, to the uncovered leg of the electro-magnet E, and its free end is allowed to project above the pole of the covered leg. Upon depressing the key K (Figure 1.) a communication is established between the main battery B, and the vibrating armature *a*, of the transmitter T. When the rivet *r*, touches the point *m*, the main circuit is completed. The currents of *z*, pass to the ground at G, and the currents of *c*, pass through K, *s*, *r*, *m*, s^1, to the line wire W, and thence through the electro-magnet E, of the receiver R, to the ground at G^1. When the rivet *r*, leaves the point *m*, the main circuit is broken. So long then as the key K, is depressed, the vibration of *a*, occasions an intermittent action of the current from the battery B, upon the line wire W, and the armature A, of the receiver R, is attracted in an intermittent manner by its electro-magnet E.

When the makes and breaks of the circuit at *m*, *r*, are timed to the normal movements of the armature A of the receiving instrument, that is, when A, is tuned to yield the same musical pitch, as the armature *a*, of the transmitting instrument, then the armature A, is thrown into strong vibration, thereby causing it to emit its musical note.

When the key K, is raised, the communication between the main battery B, and the transmitter T, is cut off, and A becomes silent. So long as the key K is depressed, a musical note is emitted by A, and the duration of this note can be made to signify the dot or dash of the Morse alphabet. Thus a telegraphic despatch can be sent from T to R, by manipulating the key K in the usual manner.

Figures 3, 4, and 5, Sheet 2, illustrate the combination of these instruments upon a telegraphic circuit, so as to permit of the simultaneous transmission of a number of telegraphic messages along a single wire.

The armatures of the transmitters and receivers that are numbered alike at all the stations, have the same pitch. Thus the transmitter T^2, of Figure 3, is the unison of the transmitter T^2. at the station represented in Figure 4. and also of the receiver R^2. at the stations shewn in Figures 3, 4, and 5.

The sounds produced by the transmitters T, T^1, T^2, &c., differ in pitch from one another, and are so arranged that each transmitter can affect one, and one only, of the receiving instruments R. R^1. $R.^2$. &c. at each station upon the line.

To illustrate the operation of this form of the invention, depress any key, say key K^1. Figure 3. — A communication being thereby established between the main battery B, and the transmitting instrument T^1, an intermittent current passes on to the main line through the receiving instruments R, R^1, R^2. &c., of Figures 3. 4. and 5. to the earth at G. Figure 5. The receiving instruments R^1. Figures 3. 4 and 5. respond so long as the key K^1 Figure 3, is depressed, and become silent the moment it is raised. The other instruments R. R^2. &c. at Stations Figures 3. 4 and 5. remain silent, so that a telegraphic message transmitted by the manipulation of key K^1. Figure 3. is received upon only its corresponding receiving instrument at each station toward that station herein shown as Figure 5. where the receiving instruments are connected directly with the earth.

The instruments shewn in Figure 4. operate as just described for those of Figure 3, the depression of each key K. K^1. or K^2. &c. operating those receiving instruments in Stations 4 and 5. that are in unison with the transmitting instrument connected with the key but does not affect the instruments in Figure 3 or in that direction.

To illustrate the simultaneous transmission of telegraphic messages by these instruments, an operator in the station shown in Figure 3. is supposed to manipulate the key K, while at the same time another operator in station Figure 4 is transmitting an entirely different despatch by the manipulation of the key K^1. The signals produced by the depression of key K, Figure 3, are received by the receivers R, of Figures 3. 4. and 5. and the signals due to the manipulation of the key K^1. Figure 4. affect the receiving instrument R^1. of Figures 4 and 5. but not R^1. of Figure 3. or of any station in the direction of Figure 3, hence, although upon this plan two or more messages may be sent simultaneously over the same circuit from the same or different stations to the same or different stations, still as the signals pass only in one direction, two line wires are required to complete communication in both directions. Intermittent currents adapted to work these instruments, may be produced without actually making and breaking the circuit as hereinbefore

described, by suddenly increasing and diminishing the intensity of the current. Such currents are termed for the sake of distinction "pulsatory." Intermittent and pulsatory currents may be of two kinds accordingly as the electrical impulses have all the same polarity, or are alternately positive and negative. In the former case they are termed "direct," in the latter "reversed" currents. These distinctions are graphically illustrated in Figures 6 and 7.

Second Plan

In order to secure communication in both directions upon a single circuit, the second portion of this invention was devised, and it is illustrated in Figures 8, 9, and 10. In these Figures the instruments employed are similar to those shown in Figures 1. 2. 3. 4 and 5. and like instruments are denoted by like letters, but instead of connecting the transmitting instruments T. T^1. T^2. &c. directly with the receiving instruments R, R^1. R^2. &c. as in Figures 3. 4. &c. — they are connected with the primary wires of an induction coil I of usual construction, and the currents induced in the secondary wires of the coil are directed to the receiving instruments R, R^1. R^2. &c. on the line wire. By this arrangement, the receiving instruments at the terminal stations Figures 8. and 10. are connected directly with the earth at G, and signals made at any one station appear at all the stations on the circuit. On this plan therefore, two or more messages may be sent simultaneously over a single circuit, in the same or in opposite directions.

Third Plan

In the methods heretofore described, employing intermittent currents of electricity, the limit to the number of signals that can be sent simultaneously over the same wire, is very speedily reached; for when a number of transmitting instruments having different rates of vibration are simultaneously making and breaking the same circuit, the effect upon the main line is practically equivalent to one continuous current. In addition to this objection local and main batteries are required at every station on the line. Similar difficulties are experienced in employing pulsatory currents; to obviate these difficulties, the plan of using an undulatory current of electricity as described in this third part of the invention, was devised.

It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter, and that when it is made to recede, a current of opposite polarity to the first appears upon the wire. When, therefore, a permanent magnet is caused to vibrate in front of the pole of an electro-magnet, an undulatory current of electricity

is induced in the coils of the electro-magnet, the undulations of which correspond in rapidity of succession to the vibrations of the magnet, in polarity to the direction of its motion, and in intensity to the amplitude of its vibration or, rather, to the velocity of its motion. A current of this character is graphically represented in line 3. Figure 7, Sheet 1,. When the permanent magnet is caused to vibrate in front of the pole of an electro-magnet which is placed in circuit with a voltaic battery, the undulatory current induced by the vibration of the permanent magnet, is superposed upon the voltaic current. When the induced impulse is of similar polarity to the voltaic current, it serves to strengthen the intensity of the latter, but when it is of opposite polarity it tends to neutralize the voltaic current. In such an arrangement the resultant effect of the vibration of the permanent magnet, is to throw the battery current into waves, as in line 3, Figure 6, by alternately increasing and diminishing the intensity of the current, such increase and diminution in the intensity of the current, does not take place with the suddenness characteristic of a pulsatory current, (see line 2. Figure 6,) but is proportional to the increase and diminution of the density of the air during the vibration of the inducing body.

The various kinds of electrical currents denominated intermittent, pulsatory and undulatory are graphically represented in Figures 6 and 7. In Figure 6, the currents are direct, that is the electrical impulses b^2, b^2, b^2, &c are all of the same polarity, either positive or negative, and in Figure 7, the currents are "reversed," that is, the electrical impulses are alternately positive and negative.

Direct intermittent current, (shewn in line 1, Figure 6,) — The impulses b^2 b^2 &c, are all of positive, or all of negative electricity, and the vertical thickness of the lines b^2 b^2 &c, measured from the zero line and z^1 z^1 represents the intensity of the current at the part observed. The horizontal extension of the line b^2 indicates the duration of the electrical impulse and the horizontal extension of the space f^2 shews the length of time the current is absent from the circuit.

Reversed intermittent current (shewn in line 1, Figure 7,) — impulses of positive electricity are represented above, and impulses of negative electricity below the zero line z^1 z^1, and the impulses b^2 d^2 are respectively positive and negative or *vice versa*.

Direct pulsatory current (shewn in line 2, Figure 6,) — The current of electricity represented, is continuous, but it changes suddenly in intensity, the elevations b^2 b^2 &c indicating the impulses of maximum intensity, and the depressions c^2 c^2 the impulses of minimum intensity. As before the vertical thickness of the line indicates the strength of the current.

Reversed pulsatory current (shewn in line 2, Figure 7) — The impulses b^2 d^2 are alternately positive and negative, without any break in the continuity of the current.

Direct undulatory current (shewn in line 3, Figure 6,)—As before the vertical thickness of the line represents the strength of the current, the elevations b^2 b^2 &c express the impulses of maximum intensity and c^2 c^2 &c those of minimum intensity. The changes of intensity as illustrated in line 3, do not occur with the suddenness characteristic of pulsatory currents as shewn in line 2, but are proportional to the changes in the density of the air during the production of a sound.

Reversed undulatory current (shewn in line 3, Figure 7,)—The elevations b^2 b^2 &c indicate impulses of positive, and the depressions d^2 d^2 impulses of negative electricity, the vertical thickness of the portions b^2 d^2 indicating the intensity of the positive or negative impulse at the part observed. The oscillations of the current above and below the zero line, correspond to the increase and diminution of the density of the air during the production of a sound, hence, the elevations b^2 b^2 &c, correspond to condensations of air and the depression d^2 d^2 &c to rarefactions the intensity of the positive or negative impulses being proportioned to the degree of density or rarity of the air.

The differences between intermittent, pulsatory and undulatory currents, will be more clearly understood by describing and illustratting the condition of the electrical current when the attempt is made to transmit two musical notes simultaneously first upon one plan and then upon the others, let the interval between the two sounds be a major third; then their rates of vibration are in the ratio of 4 to 5. Now when an intermittent current is used, the circuit is made and broken 4 times by the armature a Figure 11 Sheet 1 of one transmitting instrument, in the same time that 5 makes and breaks are caused by the armature a^1 of the other transmitting instrument. A^2 and B^2 Figure 11 represent the intermittent currents produced, four impulses of B^2 being made in the same time as five impulses of A^2; b b^2 &c Figure 11 shew where and for how long at ime the circuit is made, and f^2 f^2, &c, indicate the duration of the breaks of the circuit. The line $A^2 + B^2$, shews the total effect upon the current when the armatures a, a^1, Figure 11 are caused simultaneously to make and break the same circuit, and the combined effect upon the current passing through the receiver R, shewn at $A^2 + B^2$ Figure 11 is very nearly equivalent to a continuous current.

When many transmitting instruments of different rates of vibration, are simultaneously making and breaking the same circuit the current upon the main line become for all practical purposes continuous.

When the armatures a, a^1, are arranged upon circuit as shewn in Figure 12, pulsatory currents traverse the coils of the receiving instrument R. The line A^2 represents the pulsatory current due to the action of one armature a, and the line B^2, the action due to the other armature a^1; b^2, b^2 &c, represent impulses of maximum inten-

sity and c^2, c^2, &c impulses of minimum intensity. Four impulses of B^2 are made in the same time as five impulses of A , and the line $A^2 + B^2$ represents the total effect upon the current passing through the coils of the receiver R, when the armatures a, and a^1, are caused to vibrate simultaneously. This effect is nearly equivalent to a continuous current of mimimum intensity.

Next, consider the effect when undulatory currents are employed. Electrical undulations, induced by the vibration of a body M, Figure 13, capable of inductive action, can be represented graphically, by the same sinusoidal curve which expresses the vibration of the inducing body itself for, as above stated, the rate of oscillation in the electrical current is the same as that of the inducing body. The intensity of each induced impulse, is proportional to the velocity of the motion of the inducing body; and the polarity of each induced impulse, depends upon the direction of the motion of the inducing body to or from the pole of its electro-magnet. The sinusoidal curves A^2 and B^2, figure 13, represent graphically the electrical undulations induced in a circuit by the vibration of permanent magnets M and M^1 or other bodies capable of inducting action.

The portions b^2, b^2 &c represent impulses of positive electricity; and d^2, d^2, &c impulses of negative electricity. The horizontal line z^1, z^2, represents the zero of current, and the vertical distance of any portion of the curve b^2, or d^2, from the zero line expresses the intensity of the positive or negative impulse at the part observed.

The vibrations represented by the sinusoidal curves B^2 and A^2, Figure 13, are in the ratio aforesaid, of four to five that is four oscillations of B are made in the same line as five oscillations of A^2.

The combined effect of A^2 and B^2 when induced simultaneously on the same circuit is expressed by the curve $A^2 + B^2$, Figure 13, which is the algebraical sum of the sinusoidal curves A^2 and B^2 in Figure 14 the permanent magnets M and M^1 are caused to vibrate in front of the poles of electro-magnets e, e^1, placed in circuit with a battery B. By such an arrangement the battery current is thrown into waves. The lines A^2 B^2 represent the undulatory currents produced respectively by the vibrations of M and M^1 and as in the instances four impulses of B^2 are made in the same time as five impulses of A^2, the elevations b^2, b^2, indicate impulses of maximum intensity and the depressions c^2 c^2 &c impulses of minimum intensity. The vertical distance of any portion of the curve b^2, c^2, from the zero line z^1 z^1 expresses the intensity of the current at the part observed. The line $A^2 + B^2$ expresses the resultant effect upon a current, when the permanent magnets M, M^1 are caused to simultaneously vibrate. The curves $A^2 + B^2$, Figures 13 and 14, also indicate the actual motion of the air when the two magnets M, M are vibrated simultaneously. Thus when electrical undulations of different rates are simultaneously produced upon the same circuit the effect is exactly analogous to that occasioned in the air by the vibra-

tion of the inducing bodies; hence the co-existence upon a telegraphic circuit of electrical undulations corresponding to sounds of different pitch, is manifested not by the obliteration of the vibratory character of the current, as with intermittent and pulsatory current but by peculiarities in the shapes of the electrical undulations, or in other words, by peculiarities in the shapes of the curves which represent those undulations.

There are many ways of producing undulatory currents of electricity, dependent for effect upon the vibration or motion of bodies capable of inductive action. A few of the methods that may be employed are as follows: — When a wire through which a continuous current of electricity is passing is caused to vibrate in the neighbourhood of another wire, an undulatory current of electricity is induced in the latter. When a cylinder upon which are arranged bar magnets is made to rotate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet.

Undulations are caused in a voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration of the conducting wire itself in the neighbourhood of such bodies. Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery. The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current.

The external resistance may also be varied: for instance let water or some other liquid of high resistance form part of a voltaic circuit, then the more deeply the conducting wire is immersed in the water or other liquid, the less resistance does the liquid offer to the passage of the current. Thence the vibration of the conducting wire in water or other liquid included in the circuit occasions undulations in the current. The vertical vibration of the elements of a battery in the liquid in which they are imursed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery.

In illustration of one method of creating electrical undulations a form of apparatus is shewn in Figure 15. It is preferable to employ for this purpose an electro-magnet E, Figure 15, having a coil upon only one of its legs. A steel spring armature A is firmly clamped by one extremity to the uncovered leg *h* of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature A can be set in vibration in a variety of ways, one of which is by wind, and in vibrating it produces a musical note of a certain definite pitch.

When the electro-magnet E, is placed in a voltaic circuit B, E W

E^1, B, the armature A becomes magnetic, and the polarity of its free end is opposed to that of the magnet underneath. So long as the armature A remains at rest no effect is produced upon the voltaic current, but the moment it is set in vibration to produce its musical note a powerful inductive action takes place, and electrical undulations traverse the circuit above described. The undulatory current passing through the coil of the electro-magnet E^1 causes vibration in its armature A^1, when the armatures of the two magnets are normally in unison with one another, but the armature A^1 is unaffected by the passage of the undulatory current when the pitches of the two armatures are different.

The instruments shown in Figure 15, are like in plan to the receiving instruments R, R^1, &c, of Figures 1, 2, 3, 4, 5, 8, 9, 10. A number of instruments may be placed upon a telegraphic circuit, as in Figures 16, 17, 18. When the armature of any one of the instruments is set in vibration, all the other instruments upon the circuit, which are in unison with it, respond, but those which have normally a different rate of vibration, remain silent. Thus if R, Figure 16, be set in vibration, the armature of the receivers R, Figures 17, 18 vibrate also but all the others on the circuit, remain still. So if R^1, Figure 17, is caused to emit its musical note, the instruments R^1 shewn in Figures 16 and 18 respond. They continue sounding so long as the mechanical vibration of R^1, Figure 17, is continued, but become silent with the cessation of its motion. The duration of the sound may be used to indicate the dot or dash of the Morse alphabet, and thus a telegraphic dispatch may be indicated by alternately interrupting and renewing the sound.

When two or more instruments of different pitch are simultaneously caused to vibrate, all the instruments of corresponding pitches, upon the circuit are set in vibration each responding to only that instrument used as a transmitter, with which it is in unison. Thus the signals of R, Figure 16, are repeated by R of Figures 17 and 18 but by no other instrument upon the circuit, the signals of R^1, Figure 18, by R^1, Figures 16 and 17, and the signals of R^2, Figure 17, by R^2, Figures 16 and 18, whether R, Figure 16 R^1, Figure 18 and R^2, Figure 17, are successively or simultaneously caused to vibrate. Hence by these instruments two or more telegraphic signals or messages may be sent simultaneously over the same circuit without interfering with one another, a single battery B being used for the whole circuit. These instrument may used for the simultaneous transmission of musical notes differing in loudness as well as in pitch.

When the armature A, Figure 15, is set in vibration, the armature A^1 responds not only in pitch, but in loudnes. Thus when A vibrates with little amplitude, a very soft musical note proceeds from A^1, and when A vibrates forcibly the amplitude of the vibration of A^1 is considerably increased and the resulting sound becomes louder; so if R and R^1, Figure 16, are sounded simultaneously (R loudly and

R¹ softly) the instruments R, Figures 17 and 18 repeat loudly the signals of R Figure 16 and R¹ Figures 17 and 18 repeat softly those of R', Figure 16.

Fourth Plan.

In the plans so far described, a separate instrument is employed for every pitch and the electrical vibrations for different pitches are combined upon the wire, each armature being capable of transmitting or receiving but a single note, and thus as many separate instruments are required as there are messages or musical notes to transmit.

In this fourth part of the Invention a single instrument is employed, the armature of which can be set in vibration by a musical instrument or by the tones of a human voice or by any sound whatever.

This fourth Plan is represented in Figures 21, 22 and 23 wherein is shewn a single telephone at each station in place of the transmitting and receiving instruments heretofore described, the telephones being illustrated separately in Figures 19 and 20.

One of the ways in which the armature A, Figure 15, may be set in vibration has been stated to be by wind. Another mode is shewn in Figure 19 whereby motion can be imparted to the armature by the human voice or by means of musical instrument or by sounds of any kind.

The armature A, Figure 19, is fastened loosely by one extremity to the uncovered leg *h* of the electro-magnet E, and its other extremity is attached to the centre of a stretched membrane *n*. A cone C² is is used to converge sound vibrations upon the membrane. When a musical note is made in the neighborhood of the membrane *n* it is set in vibration, the armature A is caused to partake of the motion, and thus electrical undulations are created upon the circuit G. B, E, W, E¹, G¹. The armature A¹ is thus thrown into synchronous vibration with the armature A emitting a musical note of similar pitch to that which originated the vibration of armature A. If two or more musical notes be simultaneously sounded in the neighborhood of the cone C² the resultant motion of the air is copied by the membrane *n*, to which the armature A is attached and this armature A acting inductive by upon the current traversing the coils of the electro-magnet E occasions an increase and diminution in its utensity and the armature A¹ is thrown into vibration by the varying attraction of the electro-magnet E¹ to which it is attached, and thus imparts to the air at *n*¹, a *facsimile* copy of the motion of the air that acted upon the membrane *n* hence two or more musical notes or telegraphic messages can be sent simultaneously along a single circuit from one station to another by means of one instrument at each station.

Instead of the cone membrane and armature shewn in Figure 19, a plate of thin steel may be used, the vibrations of the plate in front of the magnet occasioned by the motion of the air during the produc-

tion of sound, changes the intensity of the current as hereinbefore described, and occasions a similar motion in a similar steel plate in front of another electro-magnet at another station in the circuit. Such a plate is shewn in Figure 20 and marked A^3 it being attached to a frame F. The telephones shewn in Figures 21 to 26 are of the kinds shewn in Figure 20. This Invention is not limited however to the use of a steel plate but includes within its scope any materials capable of inductive action upon a current of electricity. In this plan an operator at station, Figure 21, may send a telegraphic message on a certain pitch while another operator at another station, say Figure 22, is transmitting another message on a different pitch, and both sounds will be audible at all the stations in the circuit.

The receiving operators will pay attention to signals of only one pitch, hence by this plan, the simultaneous transmission of a number of telegraphic messages over a single circuit in the same or both directions with a single main battery for the whole circuit and a single telephonic instrument at each station, is rendered possible. Whatever sound is made in the neighborhood of any telephone, say, T, *e*, Figure 21, is echoed in *facsimile* by the telephones T, *e*, of all the other stations, hence this fourth plan is also adapted for the entirely new use of transmitting intelligibly, the exact sounds of articulate speech

To convey and articulate message, it is only necessary for the operator to speak in the neighborhood of a telephone, say, T, *e*, Figure 21, and for the receiving operator at another instrument, say, T, *e*, Figure 23, to listen.

If two persons speak simultaneously in the neighborhood of the same or different telephones, the utterances of the two speakers are reproduced simultaneously by all the other telephones on the same circuit, hence by this plan vocal messages may be transmitted simultaneously over the same circuit in the same or opposite directions, with one battery for the whole circuit, and one telephone at each station on the line.

In this plan of transmitting vocal utterances it is only necessary that the strength of the current should vary in intensity as the air varies in density during the utterance of the sound.

All the methods of producing undulating currents of electricity hereinbefore described may be employed in producing the undulations by which to transmit articulate messages. For instance the vibrations of a membrane may cause a platinum wire to vibrate in water or other liquid of high resistance included in the circuit, and hence will occasion changes in the intensity of the current traversing the circuit proportional to the changes in the density of the air which originally gave rise to the vibrations of the membrane, and hence the sounds uttered in the neighborhood of that membrane will be reproduced from a telephone on a distant part of the circuit.

In the fifth plan of the Invention illustrated in Figures 24, 25, and

26, the battery is omitted and a permanent magnet M^3 is substituted for the soft iron core of the electro-magnets used in the other telephones; or the coils shown in Figures 24, 25, and 26 may be induction coils of usual construction, local batteries being placed in circuit with the primary wires so as to magnetize the soft iron cores of the coils, the unduations induce in the secondary wires by the vibration of the plates A^3 being directed upon the line wire.

The sixth plan of the Invention is represented in Figures 27, 28, and 29, Figure 27 being a side view of a receiving instrument R, having a magnet E and armature as before described, and provided also with a vibratory circuit breaker V; this circuit breaker is designed for the purpose of enabling the armature A, to open or close a local circuit through the medium of the circuit breaker V; this circuit breaker consists of a light metallic lever normally resting upon the point 5, preferably adjustable so as to close a local circuit. The extremity of the circuit breaker overhangs the free end of the armature A.

When the armature A is thrown into vibration by the action of magnet E, the circuit breaker is lifted from the point 5, and it does not return until the cessation of the vibration of the armature A.

In Figure 28, an arrangement is shewn whereby the lifting of the circuit breaker V opens a local circuit, in which is placed a Morse sounder 6, or other electrical apparatus.

In Figure 29, the circuit breaker V normally "short circuits" the battery B, cutting off the current from the Morse sounder 6, or other apparatus, so that the lifting of the circuit breaker V permits the current from the battery B to actuate the telegraphic instrument 6. The vibrating circuit breaker V may be changed in construction, it only being necessary that it have normally a slower rate of vibration than the armature A by which it is vibrated.

Figure 30 represents an arrangement of transmitting instruments T T^1 T^2 &c. and receiving instruments R R^1 &c. and vibratory circuit breakers V, V^1 &c. similar to those shewn in Figures 1, 2, 27, designed to produce automatically at the receiving end of the line a *facsimile* of whatever characters or marks are presented at the transmitting end. In this plan the messages or marks to be copied may be written or printed in non metallic ink on a metallic surface F *o*, shewn in dotted lines (preferably tinfoil) or impressed upon the same. This metallic surface is placed upon a suitable metallic support S preferably made as a roller, having its axis at 7 connected with the battery B and the earth G. At the receiving end a similar support S^1, is connected in circuit with a battery B^1 and the vibratory circuit breakers V, V^1, V^2, &c, and on this support is placed a piece or strip of chemically prepared paper P *a*, shown in dotted lines.

The metallic surface F *o* on which is written the message to be transmitted is moved between the support S and the ends of a series of wires 8. 9. 10. 11. 12. 13. &c such ends being held by a non-

metallic holder or bar 14. The wires 8. 9. 10. &c communicate with the armatures *a*, of transmitters T, T¹, &c, similar to the transmitter T shewn in Figure 1. At the receiving end of the circuit the ends of a similar arrangement of wires 15, 16, 17, 18, 19 and 20 are held in place by a non-metallic holder 21, so as to rest upon the chemically prepared paper P *a*.

The metallic surface F *o* and the chemically prepared paper P *a*, are each moved in the direction of the arrows under their respective series of wires, but not necessarily at equal speed, and the characters or marks on the foil are copied on the prepared paper.

When the end of any of the wires at the transmitting end, say wire 8, rests upon the metallic foil, a communication is established between the battery B and the armature *a* of the transmitter T, the platinum rivet *r*, as heretofore described, vibrates and makes and breaks contact with the point *m*, so that an intermittent current of electricity appears upon the line wire W; so long then as the wire 8 rests on the metallic surface F *o*, the currents of *c* pass through 7, S, F *o*, 8, *r*, *m* to the line wire W, and thence by branches through the receiving instruments R, R¹, &c to the earth at G¹.

The armature of the receiving instrument R, which is in unsion with the armature *a* of the transmitter T, is thrown into vibration by the passage of the intermittent current, but the armatures of the other transmitting instruments R¹, R², &c, having a different rate of vibration from the armature of T, do not respond.

The armature of the receiving instrument R in the course of its vibration, lifts the spring lever V, breaking the circuit B¹ S¹, P, *a*, 15, V, B¹. So long then as the end of the wire 8 rests upon the metallic surface F, *o*, the local circuit in which the wire 15 is placed remains open, and thus no mark is made upon the paper P, *a*, under wire 15.

When, during the movement of the metallic surface F, *o*, a portion of the non-metallic ink comes under the end of the wire 8; the connection between the battery B and transmitter T is broken, the receiver R becomes silent, the spring-lever V returns to its normal position, closing the circuit above described, and a mark is made upon that part of the chemically-prepared paper P, *a*, under wire 15.

Each wire 9, 10 &c. operates in a like manner to the wire 8, and the wires 16, 17, 18 &c. operate as described for wire 15.

Any of the ordinary chemically prepared paper used in connection with ordinary systems of chemical or autograph telegraphs may be used.

SPECIFICATION in pursuance of the conditions of the Letters Patent filed by the said William Morgan-Brown, in the Great Seal Patent Office, on the 9th June 1877.

WILLIAM MORGAN-BROWN of the Firm of Brandon and Morgan-Brown Engineers and Patent Agents of 38 Southampton Buildings London, and 1 Rue Laffitte, Paris. "IMPROVEMENTS IN ELECTRIC TELEPHONY (TRANSMITTING OR CAUSING SOUNDS FOR TELEGRAPHIC MESSAGES) AND TELEPHONIC APPARATUS." A communication from abroad by Alexander Graham Bell of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology.

This Invention of Improvements in electric telephony (transmitting or causing sounds for telegraphing messages) and telephonic apparatus relates to electric telephony and telephonic apparatus.

In all previous systems of telegraphy messages have been received either by means of chemical changes produced by the action of the electrical current as in the various forms of automatic and autographical telegraphs, or by means of the mechanical movement of a portion of the receiving instrument operating to produce a visible signal as in needle telegraphs, a mark upon paper or other material as in printing telegraphs, or a sound as in the Morse system. Upon these and all other plans it has been found difficult if not impossible to distinguish between more than four messages transmitted simultaneously over the same circuit, two in each direction.

This present invention relates to the reproduction by the necessary receiving instruments of any particular sounds or combinations of sounds through the agency of an electric current whereby a multiplicity of telegraphic messages may be sent simultaneously over a single circuit in the same or in opposite directions and received without confusion and whereby articulate speech may be electrically transmitted.

The Invention relates to the production or transmission of musical notes by means of undulatory currents of electricity, one battery being used for the whole circuit whereby two or more telegraphic signals or messages can be transmitted simultaneously over a single circuit in the same or in opposite directions.

The Invention also relates to the electrical production or transmission of sounds of every kind by means of undulatory currents of electricity, whereby not only musical sounds but articulate speech can be transmitted over a telegraph line and two or more messages be simultaneously sent over a single circuit in the same or in opposite directions.

The Invention also relates to the electrical production or transmission of sounds of every kind, without a battery, by means of undulatory currents of electricity, whereby not only musical notes

but articulate speech can be transmitted over a telegraph line, and two or more messages be sent simultaneously over a single circuit in the same or in opposite directions.

The Invention also relates to the automatic reception of signals or messages by introducing at the receiving end of the line a local circuit containing a vibratory circuit breaker, whereby telephonic signals or messages may be automatically recorded.

The Invention also relates to the application of electric telephony to autographic telegraphy whereby characters or marks of any description may be copied in *facsimile* at the receiving end of the line.

First Plan.

The first method of and apparatus for transmitting two or more telegraphic messages or signals simultaneously along a single wire by the employment of transmitting instruments, each of which occasions a succession of electrical impulses differing in rate from the others and of receiving instruments each tuned to a pitch at which it will be put in vibration to produce its fundamental note by one only of the transmitting instruments as devised by my communicator, is illustrated in Figures 1 and 2 of Sheet 1, and in Figures 3. 4 and 5. of Sheet 2

The transmitting instrument T (Figure 1) consists of an electro-magnet *e*, having a steel spring armature *a*, which is kept in continuous vibration by the action of a local battery *b*. The armature *a* in the course of its vibration brings the platinum rivet *r* alternately into contact with two platinum points *l* and *m*, one *l*, being placed in a local circuit *b*, s^2, *e*, *l*, *r*, s^3, *b*, and the other, *m*, communicating with the line wire W through the screw cap s^1.

The receiving instrument R, shown in plan in Figure 1, and in elevation in Figure 2, consists of an electro-magnet E, having a coil upon only one of its legs. A steel-spring armature A, is firmly clamped by one extremity, to the uncovered leg of the electro-magnet E, and its free end is allowed to project above the pole of the covered leg. Upon depressing the key K (Figure 1) a communication is established between the main battery B and the vibrating armature *a* of the transmitter T. When the rivet *r*, touches the point *m*, the main circuit is completed. The currents of *z* pass to the ground at G and the currents of *c* pass through K. *s*. *r*. *m*. s^1. to the line wire W, and thence through the electro-magnet E of the receiver R to the ground at G^1. When the rivet *r* leaves the point *m* the main circuit is broken. So long then as the key K is depressed, the vibration of *a* occasions an intermittent action of the current from the battery B upon the line wire W and the armature A of the receiver R is attracted in an intermittent manner by its electro-magnet E.

When the makes and breaks of the circuit at *m*. *r*. are timed to the normal movements of the armature A of the receiving instrument, that is, when A is tuned to yield the same musical pitch as the armature *a* of the transmitting instrument, then the armature A is thrown into strong vibration, thereby causing it to emit its musical note.

When the key K is raised, the communication between the main battery B and the transmitter T is cut off and A becomes silent. So long as the key K is depressed, a musical note is emitted by A and the duration of this note can be made to signify the dot or dash of the Morse alphabet. Thus a telegraphic despatch can be sent from T to R by manipulating the key K in the usual manner.

Figures 3. 4, and 5, Sheet 2, illustrate the combination of these instruments upon a telegraphic circuit so as to permit of the simultaneous transmission of a number of telegraphic messages along a single wire.

The armatures of the transmitters and receivers that are numbered alike at all the stations have the same pitch. Thus the transmitter T^2 of Figure 3 is the unison of the transmitter T^2 at the station represented in Figure 4, and also of the receiver R^2 at the stations shown in Figures 3, 4, and 5.

The sounds produced by the transmitters T. T^1. T^9. &c. differ in pitch from one another, and are so arranged that each transmitter can affect one and one only of the receiving instruments R. R^1. R^2. &c. at each station upon the line.

To illustrate the operation of this form of the invention, depress any key say key, K^1, Figure 3. A communication being thereby established between the main battery B, and the transmitting instrument T^1, an intermittent current passes on to the main line through the receiving instruments R. R^1. R^2. &c. of Figures 3, 4, and 5, to the earth at G, Figure 5. The receiving instruments R^1, Figures 3, 4, and 5, respond so long as the key K^1, Figure 3, is depressed and become silent the moment it is raised. The other instruments R. R^2. &c. at stations Figures 3. 4. and 5, remain silent so that a telegraphic message transmitted by the manipulation of key K^1, Figure 3, is received upon only its corresponding receiving instrument at each station toward that station herein shown as Figure 5, where the receiving instruments are connected directly with the earth.

The instruments shown in Figure 4, operate as just described for those of Figure 3, the depression of each key K. K^1. or K^2. &c. operating those receiving instruments in stations 4 and 5 that are in unison with the transmitting instrument connected with the key, but does not affect the instruments in Figure 3 or in that direction.

To illustrate the simultaneous transmission of telegraphic messages by these instruments an operator in the station shown in Fig-

ure 3 is supposed to manipulate the key K, while at the same time another operator in station, Figure 4, is transmitting an entirely different despatch by the manipulation of the key K^1. The signals produced by the depression of key K, Figure 3, are received by the receivers R of Figures 3. 4 and 5, and the signals due to the manipulation of the key K^1, Figure 4, affect the receiving instrument R^1 of Figures 4 and 5, but not R^1 of Figure 3, or of any station in the direction of Figure 3. Hence although upon this plan two or more messages may be sent simultaneously over the same circuit from the same or different stations to the same or different stations, still as the signals pass only in one direction two line wires are required to complete communication in both directions. Intermittent currents adapted to work these instruments may be produced without actually making and breaking the circuit as hereinbefore described by suddenly increasing and diminishing the intensity of the current. Such currents are termed for the sake of distinction "pulsatory." Intermittent and pulsatory currents may be of two kinds accordingly as the electrical impulses have all the same polarity or are alternately positive and negative. In the former case they are termed "direct" in the latter "reversed" currents. These distinctions are graphically illustaated in Figures 6 and 7.

Second Plan as devised by my communicator.

In order to secure communication in both directions upon a single circuit this second plan was devised and it is illustrated in Figures 8. 9 and 10. In these Figures the instruments employed are similar to those shown in Figures 1. 2. 3. 4 and 5 and like instruments are denoted by like letters but instead of connecting the transmitting instruments T. T^1. T^2. &c. directly with the receiving instruments R. R^1. R^2. &c. as in Figures 3. 4 &c. they are connected with the primary wires of an induction coil, I, of usual construction, and the currents induced in the secondary wires of the coil are directed to the receiving instruments R. R^1. R^2. &c. on the line wire. By this arrangement the receiving instruments at the terminal stations Figures 8 and 10 are connected directly with the earth at G. and signals made at any one station appear at all the stations on the circuit. On this plan therefore two or more messages may be sent simultaneously over a single circuit in the same or in opposite directions.

Third Plan.

In the methods heretofore described employing intermittent currents of electricity the limit to the number of signals that can be sent simultaneously over the same wire is very speedily reached for when a number of transmitting instruments having different rates of vibration are simultaneously making and breaking the same circuit

the effect upon the main line is practically equivalent to one continuous current. In addition to this objection local and main batteries are required at every station on the line. Similar difficulties are experienced in employing pulsatory currents. To obviate these difficulties the plan of using an undulatory current of electricity as described in this part of the Invention was devised.

It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter and that when it is made to recede a current of opposite polarity to the first appears upon the wire. When therefore a permanent magnet is caused to vibrate in front of the pole of an electro-magnet an undulatory current of electricity is induced in the coils of the electro-magnet the undulations of which correspond in rapidity of succession to the vibrations of the magnet, in polarity to the direction of its motion and in intensity to the amplitude of its vibration or rather to the velocity of its motion. A current of this character is graphically represented in line 3 Figure 7, Sheet 1. When the permanent magnet is caused to vibrate in front of the pole of an electro-magnet which is placed in circuit with a voltaic battery, the undulatory current induced by the vibration of the permanent magnet is superposed upon the voltaic current. When the induced impulse is of similar polarity to the voltaic current it serves to strengthen the intensity of the latter but when it is of opposite polarity it tends to neutralize the voltaic current. In such an arrangement the resultant effect of the vibration of the permanent magnet is to throw the battery currents into waves as in line 3, Figure 6, by alternately increasing and diminishing the intensity of the current. Such increase and diminution in the intensity of the current does not take place with the suddenness characteristic of a pulsatory current (see line 2 Figure 6) but is proportional to the increase and diminution of the density of the air during the vibration of the inducing body.

The various kinds of electrical currents denominated intermittent, pulsatory, and undulatory are graphically represented in Figures 6 and 7. In Figure 6 the currents are direct, that is, the electrical impulses b^2. b^2. b^2. &c. are all of the same polarity either positive or negative, and in Figure 7 the currents are "reversed," that is, the electrical impulses are alternately positive and negative.

Direct intermittent current. (shown in Line 1 Figure 6) — The impulses b^2. b^2. &c are all of positive or all of negative electricity and the vertical thickness of the lines b^2. b^2. &c. measured from the zero line z^1. z^1. represents the intensity of the current at the part observed. The horizontal extension of the line b^2 indicates the duration of the electrical impulse and the horizontal extension of the space f^2 shows the length of time the current is absent from the circuit.

Reversed intermittent current. (shown in line 1 Figure 7)—Impulses of positive electricity are represented above, and impulses of

negative electricity below the zero line z^1. z^1. and the impulses b^2. d^2. are respectively positive and negative or *vice versa*.

Direct pulsatory current (shown in line 2, Figure 6)—The current of electricity represented is continuous, but it changes suddenly in intensity, the elevations b^2. b^2. &c. indicating the impulses of maximum intensity, and the depressions c^2. c^2. the impulses of minimum intensity. As before the vertical thickness of the line indicates the strength of the current.

Reversed pulsatory current (shown in line 2 Figure 7)—The impulses b^2. d^2. are alternately positive and negative without any break in the continuity of the current.

Direct undulatory current. (shown in line 3 Figure 6)—As before the vertical thickness of the line represents the strength of the current, the elevations b^2. b^2. &c. express the impulses of maximum intensity and c^2. c^2. &c. those of minimum intensity. The changes of intensity as illustrated in line 3 do not occur with the suddenness characteristic of pulsatory currents as shown in line 2 but are proportional to the changes in the density of the air during the production of a sound.

Reversed undulatory current (shown in line 3 Figure 7)—The elevations b^2. b^2. &c. indicate impulses of positive and the depressions d^2. d^2. impulses of negative electricity, the vertical thickness of the portions, b^2. d^2. indicating the intensity of the positive or negative impulse at the part observed. The oscillations of the current above and below the zero line, correspond to the increase and diminution of the density of the air during the production of a sound, hence the elevations b^2. b^2. &c. correspond to condensations of air, and the depressions d^2. d^2. &c. to rarefactions, the intensity of the positive or negative impulses being proportioned to the degree of density or rarity of the air.

The differences between intermittent pulsatory and undulatory currents will be more clearly understood by describing and illustrating the condition of the electrical current when the attempt is made to transmit two musical notes simultaneously first upon one plan and then upon the others. Let the interval between the two sounds be a major third; then their rates of vibration are in the ratio of 4 to 5. Now when an intermittent current is used, the circuit is made and broken four times by the armature *a*, Figure 11, Sheet 1, of one transmitting instrument, in the same time that five makes and breaks are caused by the armature a^1 of the other transmitting instrument. A^2 and B^2, Figure 11, represent the intermittent currents produced, four impulses of B^2 being made in the same time as five impulses of A^2. b^2. b^2. &c., Figure 11, show where and for how long time the circuit is made, and f^2. f^2. &c. indicate the duration of the breaks of the circuit. The line $A^2 + B^2$ shows the total effect upon the current when the armatures *a*. a^1, Figure 11, are caused simultaneously to make and break the same circuit and the combined effect upon the

current passing through the receiver R shown at $A^2 + B^2$, Figure 11, is very nearly equivalent to a continuous current.

When many transmitting instruments of different rates of vibration are simultaneously making and breaking the same circuit, the current upon the main line becomes, for all practical purposes continuous.

When the armatures *a*, *a*, are arranged upon circuit as shown in Figure 12, pulsatory currents traverse the coils of the receiving instrument R. The line A^2 represents the pulsatory current due to the action of one armature *a* and the line B^2; the action due to the other armature a^1. b^2. b^2. &c. represent impulses of maximum intensity, and c^2. c^2. &c. impulses of minimum intensity. Four impulses of B^2 are made in the same time as five impulses of A^2, and the line $A^2 + B^2$ represents the total effect upon the current passing through the coils of the receiver R when the armatures *a* and a^1 are caused to vibrate simultaneously. This effect is nearly equivalent to a continuous current of minimum intensity.

Next consider the effect when undulatory currents are employed. Electrical undulations induced by the vibration of a body M, Figure 13, capable of inductive action, can be represented graphically by the same sinusoidal curve which expresses the vibration of the inducing body itself, for as above stated the rate of oscillation in the electrical current is the same as that of the inducing body. The intensity of each induced impulse is proportional to the velocity of the motion of the inducing body, and the polarity of each induced impulse depends upon the direction of the motion of the inducing body to or from the pole of its electro-magnet. The sinusoidal curves A^2 and B^2, Figure 13, represent graphically the electrical undulations induced in a circuit by the vibration of permanent magnets M and M^1, or other bodies capable of inductive action.

The portions b^2. b^2. &c. represent impulses of positive electricity, and d^2. d^2. &c impulses of negative electricity. The horizontal line z^1. z^1. represents the zero of current and the vertical distance of any portion of the curve b^2 or d^2 from the zero line, expresses the intensity of the positive or negative impulse at the part observed.

The vibrations represented by the sinusoidal curves B^2 and A^2, Figure 13, are in the ratio aforesaid of four to five, that is, four oscillations of B^2 are made in the same time as five oscillations of A^2. The combined effect of A^2 and B^2, when induced simultaneously on the same circuit, is expressed by the curve $A^2 + B^2$, Figure 13, which is the algebraical sum of the sinusoidal curves A^2 and B^2. In Figure 14, the permanent magnets M and M^1 are caused to vibrate in front of the poles of electro-magnets *e* . e^1. placed in circuit with a battery B. By such an arrangement the battery current is thrown into waves. The lines A^2 and B^2 represent the undulatory currents produced respectively by the vibrations of M and M^1, and, as in the other instances, four impulses of B^2 are made in the same time as

five impulses of A^2. The elevations b^2. b^2. &c. indicate impulses of maximum intensity, and the depressions c^2 c^2. &c. impulses of minimum intensity. The vertical distance of any portion of the curve b^2. c^2. from the zero line z^1. z^1. expresses the intensity of the current at part observed. The line $A^2 + B^2$ expresses the resultant effect upon the current when the permanent magnets M M^1 are caused simultaneously to vibrate. The curves $A^2 + B^2$, Figures 13 and 14, also indicate the actual motion of the air when the two magnets M M^1 are vibrated simultaneously. Thus when electrical undulations of different rates are simultaneously produced upon the same circuit, the effect is exactly analogous to that occasioned in the air by the vibration of the inducing bodies. Hence the co-existence upon a telegraphic circuit of electrical undulations corresponding to sounds of different pitch is manifested not by the obliteration of the vibratory character of the current, as with intermittent and pulsatory currents, but by peculiarities in the shapes of the electrical undulations, or in other words, by peculiarities in the shapes of the curves which represent those undulations.

There are many ways of producing undulatory currents of electricity dependent for effect upon the vibration or motion of bodies capable of inductive action. A few of the method that may be employed are as follows: When a wire through which a continuous current of electricity is passing is caused to vibrate in the neighbourhood of another wire, an undulatory current of electricity is induced in the latter. When a cylinder upon which are arranged bar magnets is made to rotate in front of the pole of an electro-magnet an undulatory current of electricity is induced in the coils of the electro-magnet.

Undulations are caused in a voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration of the conducting wire itself in the neighbourhood of such bodies. Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit or by alternately increasing and diminishing the power of the battery. The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery therefore occasions an undulatory action in the voltaic current.

The external resistance may also be varied. For instance let water or some other liquid of high resistance form part of a voltaic circuit then the more deeply the conducting wire is immersed in the water or other liquid the less resistance does the liquid offer to the passage of the current. Hence the vibration of the conducting wire in water or other liquid included in the circuit occasions undulations in the current. The vertical vibration of the elements of a battery in the liquid in which they are immersed produces an undulatory

action in the current by alternately increasing and diminishing the power of the battery.

In illustration of one method of creating electrical undulations, a form of apparatus is shown in Fig. 15. It is preferable to employ for this purpose an electro-magnet E, Figure 15, having a coil upon only one of its legs. A steel spring armature, A is firmly clamped by one extremity to the uncovered leg, *h*, of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature A can be set in vibration in a variety of ways one of which is by wind, and in vibrating it produces a musical note of a certain definite pitch.

When the electro-magnet, E, is placed in a voltaic circuit B, E, W. E^1. B, the armature A becomes magnetic, and the polarity of its free end is opposed to that of the magnet underneath. So long as the armature A remains at rest, no effect is produced upon the voltaic current, but the moment it is set in vibration to produce its musical note, a powerful inductive action takes place and electrical undulations traverse the circuit above described. The undulatory current passing through the coil of the electro-magnet E^1 causes vibration in its armature A^1 when the armatures of the two magnets are normally in unison with one another, but the armature A^1 is unaffected by the passage of the undulatory current, when the pitches of the two armatures are different.

The instruments shown in Figure 15 are like in plan to the receiving instruments R R^1, &c., of Figures 1. 2 3. 4. 5. 8. 9. 10. A number of instruments may be placed upon a telegraphic circuit, as in Figures 16, 17, 18. When the armature of any one of the instruments is set in vibration, all the other instruments upon the circuit which are in unison with it, respond, but those which have normally a different rate of vibration remain silent. Thus if R, Figure 16, is set in vibration, the armatures of the receivers R, Figures 17. 18, vibrate also, but all the others on the circuit remain still. So if R^1, Figure 17, is caused to emit its musical note, the instruments R^1, shown in Figures 16 and 18, respond. They continue sounding so long as the mechanical vibration of R^1, Figure 17, is continued, but become silent with the cessation of its motion. The duration of the sound may be used to indicate the dot or dash of the Morse alphabet, and thus a telegraphic despatch may be indicated by alternately interrupting and renewing the sound.

When two or more instruments of different pitch are simultaneously caused to vibrate, all the instruments of corresponding pitches upon the circuit are set in vibration, each responding to only that instrument used as a transmitter with which it is in unison. Thus the signals of R, Figure 16, are repeated by R of Figures 17 and 18, but by no other instrument upon the circuit. The signals of R^1, Figure 18, by R^1, Figures 16 and 17, and the signals of R^2, Figure 17, by R^2, Figures 16 and 18, whether R, Figure 16, R^1, Figure 18, and R^2,

Figure 17, are successively or simultaneously caused to vibrate. Hence by these instruments two or more telegraphic signals or messages may be sent simultaneously over the same circuit without interfering with one another, a single battery, B, being used for the whole circuit. These instruments may be used for the simultaneous transmission of musical notes differing in loudness as well as in pitch.

When the armature A, Figure 15, is set in vibration, the armature A^1 responds not only in pitch but in loudness. Thus when A vibrates with little amplitude a very soft musical note proceeds from A^1, and when A vibrates forcibly, the amplitude of the vibration of A^1 is considerably increased, and the resulting sound becomes louder. So if R and R^1, Figure 16, are sounded simultaneously (R loudly and R^1 softly), the instruments R, Figures 17 and 18, repeat loudly the signals of R, Figure 16, and R^1, Figures 17 and 18, repeat softly those of R^1, Figure 16.

Fourth Plan.

In the plans so far described a separate instrument is employed for every pitch, and the electrical vibrations for different pitches are combined upon the wire, each armature being capable of transmitting or receiving but a single note, and thus as many separate instruments are required as there are messages or musical notes to transmit.

In this fourth part of the invention a single instrument is employed, the armature of which can be set in vibration by a musical instrument or by the tones of the human voice, or by any sound whatever.

This fourth plan is represented in Figures 21, 22 and 23, wherein is shown a single telephone at each station, in place of the transmitting and receiving instruments heretofore described, the telephones being illustrated separately in Figures 19 and 20.

One of the ways in which the armature A, Figure 15, may be set in vibration has been stated to be by wind. Another mode is shown in Figure 19, whereby motion can be imparted to the armature by the human voice, or by means of a musical instrument, or by sounds of any kind.

The armature A, Figure 19, is fastened loosely by one extremity to the uncovered leg *h* of the electro-magnet E, and its other extremity is attached to the centre of a stretched membrane *n*. A cone C^2 is used to converge sound vibrations upon the membrane. When a musical note is made in the neighbourhood of the membrane *n* it is set in vibration, the armature A is forced to partake of the motion, and thus electrical undulations are created upon the circuit G. B. E. W. E^1. G^1. The armature A^1 is thus thrown into synchronous vibration with the armature A, emitting a musical note of similar pitch to that which originated the vibration of armature A. If two or more musical notes be simultaneously sounded in the neighbourhood of the cone C^2, the resultant motion of the air is copied by the membrane

n to which the armature A is attached and this armature A, acting inductively upon the current traversing the coils of the electro-magnet E, occasions an increase and diminution in its intensity and the armature A^1 is thrown into vibration by the varying attraction of the electro-magnet E^1 to which it is attached and thus imparts to the air at n^1 a *facsimile* copy of the motion of the air that acted upon the membrane n, hence two or more musical notes or telegraphic messages can be sent simultaneously along a single circuit from one station to another by means of one instrument at each station.

Instead of the cone membrane and armature shown in Figure 19 a plate of thin steel may be used the vibrations of the plate in front of the magnet occasioned by the motion of the air during the production of sound changes the intensity of the current as hereinbefore described and occasions a similar motion in a similar steel plate in front of another electro-magnet at another station in the circuit. Such a plate is shown in Figure 20 and marked A^3 it being attached to a frame F. The telephones shown in Figures 21 to 26 are of the kind shown in Figure 20. This invention is not limited however to the use of a steel plate but includes within its scope any material capable of inductive action upon a current of electricity. In this plan an operator at Station, Figure 21, may send a telegraphic message on a certain pitch while another operator at another station, say, Figure 22, is transmitting another message on a different pitch and both sounds will be audible at all the stations in the circuit.

The receiving operators will pay attention to signals of only one pitch, hence by this plan the simultaneous transmission of a number of telegraphic messages over a single circuit in the same or both directions with a single main battery for the whole circuit and a single telephonic instrument at each station is rendered possible. Whatever sound is made in the neighbourhood of any telephone say T. *e.* Figure 21, is echoed in *fac simile* by the telephones T. *e.* of all the other stations, hence this fourth plan is also adapted for the entirely new use of transmitting intelligibly the exact sounds of articulate speech.

To convey an articulate message it is only necessary for the operator to speak in the neighbourhood of a telephone say *T. e.* Figure 21, and for the receiving operator at another instrument say *T. e.* Figure 23, to listen.

If two persons speak simultaneously in the neighbourhood of the same or different telephones the utterances of the two speakers are reproduced simultaneously by all the other telephones on the same circuit, hence by this plan vocal messages may be transmitted simultaneously over the same circuit in the same or opposite directions with one battery for the whole circuit, and one telephone at each station on the line. In this plan of transmitting vocal utterance it is only necessary that the strength of the current should vary in

intensity as the air varies in density during the utterance of the sound.

All the methods of producing undulatory currents of electricity hereinbefore described may be employed in producing the undulations by which to transmit articulate messages. For instance the vibrations of a membrane may cause a platinum wire to vibrate in water or other liquid of high resistance included in the circuit, and hence will occasion changes in the intensity of the current traversing the circuit proportional to the changes in the density of the air which originally gave rise to the vibrations of the membrane, and hence the sounds uttered in the neighbourhood of that membrane will be reproduced from a telephone on a distant part of the circuit.

In the fifth plan of the Invention illustrated in Figures 24, 25 and 26 the battery is omitted and a permanent magnet M^3 is substituted for the soft iron core of the electro-magnets used in the other telephones. Or the coils shown in Figures 24, 25 and 26 may be induction coils of usual construction, local batteries being placed in circuit with the primary wires so as to magnetize the soft iron cores of the coils. The undulations induced in the secondary wires by the vibration of the plates A^3 being directed upon the line wire.

The sixth plan of the Invention is represented in Figures 27, 28 and 29 Figure 27 being a side view of a receiving instrument, R, having a magnet E, and armature A, as before described, and provided also with a vibratory circuit breaker V. This circuit breaker is designed for the purpose of enabling the armature A to open or close a local circuit through the medium of the circuit breaker V. This circuit breaker consists of a light metallic lever normally resting upon the point, 5, preferably adjustable so as to close a local circuit. The extremity of the circuit breaker overhangs the free end of the armature A. When the armature A is thrown into vibration by the action of magnet E, the circuit breaker is lifted from the point 5 and it does not return until the cessation of the vibration of the armature A.

In Figure 28 an arrangement is shown whereby the lifting of the circuit breaker V opens a local circuit in which is placed a Morse sounder 6, or other electrical apparatus.

In Figure 29 the circuit breaker V normally "short circuits" the battery B cutting off the current from the Morse sounder 6, or other apparatus, so that the lifting of the circuit breaker V permits the current from the battery B to actuate telegraphic instrument 6. The vibrating circuit breaker V may be changed in construction, it only being necessary that it have normally a slower rate of vibration than the armature A by which it is vibrated.

Figure 30 represents an arrangement of transmitting instruments T. T^1. T^2. &c and receiving instruments R. R^1. &c and vibratory circuit breakers V. V^1. &c. similar to those shown in Figures 1. 2. 27. designed to produce automatically at the receiving end of the line a

facsimile of whatever characters or marks are presented at the transmitting end. In this plan the messages or marks to be copied may be written or printed in non-metallic ink on a metallic surface, F, *o*, shown in dotted lines (preferably tinfoil) or impressed upon the same. This metallic surface is placed upon a suitable metallic support S, preferably made as a roller having its axis at 7 connected with the battery B and the earth G. At the receiving end a similar support S^1 is connected in circuit with a battery B^1 and the vibratory circuit breakers V V^1 V^2 &c and on this support is placed a piece or strip of chemically prepared paper, P, *a*, shown in dotted lines.

The metallic surface F, *o*, on which is written the message to be transmitted is moved between the support S and the ends of a series of wires 8. 9. 10. 11. 12. 13 &c. such ends being held by a non-metallic holder or bar 14. The wires 8. 9. 10 &c. communicate with the armatures *a* of transmitters T T^1 &c. similar to the transmitter T shown in Figure 1.

At the receiving end of the circuit the ends of a similar arrangement of wires 15, 16. 17. 18. 19 and 20 are held in place by a non-metallic holder 21 so as to rest upon the chemically prepared paper P, *a*.

The metallic surface F, *o*, and the chemically prepared paper P, *a*, are each moved in the direction of the arrows under their respective series of wires but not necessarily at equal speed, and the characters or marks on the foil are copied on the prepared paper.

When the end of any of the wires at the transmitting end, say wire 8, rests upon the metallic foil a communication is established between the battery B and the armature *a* of the transmitter T; the platinum rivet *r*, as heretofore described, vibrates and makes and breaks contract with the point *m* so that an intermittent current of electricity appears upon the line wire W. So long then as the wire 8 rests on the metallic surface F, *o*, the currents of *c* pass through 7, S, F *o*, 8, *r*, *m*, to the line wire W, and thence by branches through the receiving instruments R R^1 &c. to the earth at G^1.

The armature of the receiving instrument R, which is in unison with the armature *a* of the transmitter T, is thrown into vibration by the passage of the intermittent current, but the armatures of the other transmitting instruments R^1 R^2 &c. having a different rate of vibration from the armature of T do not respond.

The armature of the receiving instrument R in the course of its vibration lifts the spring lever V breaking the circuit B^1, S^1, P, *a*, 15, V, B^1. So long then as the end of the wire 8 rests upon the metallic surface F, *o*, the local circuit in which the wire 15 is placed remains open, and thus no mark is made upon the paper P, *a*, under wire 15.

When during the movement of the metallic surface F, *o*, a portion of the non-metallic ink comes under the end of the wire 8, the connection between the battery B and transmitter T is broken, the receiver R becomes silent, the spring lever V returns to its normal

position closing the circuit above described, and a mark is made upon that part of the chemically prepared paper P, *a*, under wire 15.

Each wire 9, 10 &c. operates in a like manner to the wire, 8, and the wires 16, 17. 18. &c. operate as described for wire 15.

Any of the ordinary chemically prepared paper used in connection with ordinary systems of chemical or autograph telegraphs may be used.

Referring again to the fifth plan the magnet may be of the horse-shoe form as shown at 24 in Figure 31, and the coils of insulated wire, 25, may surround soft iron cores or pole pieces, 26, screwed or otherwise fastened to the ends of the magnet 24. The cores or pole pieces are placed near the face of the metallic plate A^3, it being attached to a cup-shaped block, 28, having a central orifice, 29, for the reception of a speaking or hearing tube to convey sounds to or from the plate A^3. The magnet is attached to a stud, 30, adapted to be moved in suitable grooves in the base, 31, by means of a screw, 32, having its end connected with the stand, the body of the screw being fitted to turn in a screw threaded stud. The movements of the screw are just the distance between the pole of the magnet and the plate A^3, and permit the poles to be placed almost in contact with the plate. The coils may be placed about the ends of the magnet 24, and the soft iron pole pieces be omitted.

Figure 32 represents in perspective a telephone of the kind shown in Figure 31 when placed within a sounding box 33. The coils will preferably be very thin and be placed at the extremity or extremities of the magnet. One, two, or more magnetic poles with coils may be placed near a plate to intensify the effect.

The soft iron core and coil may be attached to the plate instead of the magnet, or the core may be placed upon the plate and the coil on the magnet, or *vice versa*. The magnet may be made to vibrate instead of the plate.

Having now described and particularly set forth the nature of the said invention, and the manner of carrying the same into effect I would have it understood that what I claim is,—

First. The method herein described of producing or transmitting musical notes by means of undulatory currents of electricity, whereby two or more telegraphic signals or messages can be transmitted simultaneously over a single circuit in the same or opposite directions.

Second. In a system of multiple telegraphy wherein undulatory currents of electricity are employed, the employment of receiving instruments, the armatures of which are tuned to definite pitches so as to vibrate only when a sound of like pitch is transmitted, substantially as described.

Third. A system of telegraphy in which the receiver is set in vibration by the employment of undulatory currents of electricity, substantially as set forth.

Fourth. The combination, substantially as set forth, of a perma-

nent magnet or other body capable of inductive action with a closed circuit, so that the vibration of the one shall occasion electrical undulations in the other or in itself, and this I claim whether the permanent magnet be set in vibration in the neighbourhood of the conducting wire forming the circuit, or whether the conducting wire be set in vibration in the neighbourhood of the permanent magnet, or whether the conducting wire and the permanent magnet, both simultaneously, be set in vibration in each other's neighbourhood.

Fifth. The method of producing undulations in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration or motion of the conducting wire itself in the neighbourhood of such bodies, as set forth.

Sixth. The method of producing undulations in a continuous voltaic circuit by gradually increasing and diminishing the resistance of the circuit, or by gradually increasing and diminishing the power of the battery, as set forth.

Seventh. The method of transmitting vocal or other sounds electrically by causing the intensity of an electrical current to vary in a manner proportional to the variations of density produced in the air by the said sounds.

Eighth. The method of transmitting vocal or other sounds electrically by causing the intensity and polarity of an electrical current to vary in a manner proportional to the velocity and the direction of motion of the particles of air during the production of the sounds.

Ninth. The union upon and by means of an electric circuit of two or more telephones constructed for operation substantially as described, so that if the plate armature of any one of the said instruments be moved in any manner the armatures of all the other telephones upon the same circuit will be moved in like manner, and if the transmitter armature be moved or vibrated by sound like sounds will be produced by the motion or vibration of the armature of the other telephones upon the circuit.

Tenth. In a system of electric telegraph or telephony consisting of transmitting and receiving instruments united upon an electric circuit I claim the production in the armature of each receiving instrument of any given motion by subjecting said armature to an attraction varying in intensity, however such variation may be produced in the magnet, and hence I claim the production of any given sound or sounds from the armature of the receiving instrument by subjecting said armature to an attraction varying in intensity in such manner as to throw the armature into that form of vibration which characterizes the given sound or sounds.

Eleventh. The combination with an electro-magnet of a plate of iron or steel or other material capable of inductive action which can be thrown into vibration by the movement of surrounding air, or by the attraction of a magnet.

Twelfth. In combination with a plate and electro-magnet as before claimed, the means herein described or their mechanical equivalents of adjusting the relative position of the two, so that without touching they may be set as closely together as possible.

Thirteenth. In an electric telephone the combination with the plate of a magnet having coils upon the end or ends of the magnet nearest the plate, substantially as described.

Fourteenth. The combination with an electric telephone, such as described, of a sounding box, substantially as herein shown and set forth.

Fifteenth. In combination with an electric telephone, as herein described, the employment of a speaking or hearing tube for conveying sounds to or from the telephone, substantially as set forth.

Sixteenth. In an electric telephone the combination with a permanent magnet and plate armature of a soft iron pole piece forming the core for the coil, substantially as described.

Seventeenth. In a system of telegraphy in which the vibrating receiver operates the circuit breaker of a local circuit independent of said receiver, as described, a vibratory circuit breaker for said local circuit, consisting of a light spring arm, whose free end overlaps the reed or vibrating portion of the receiver in combination with a portion of the receiver in combination with a contact tip or point in said circuit with which the spring arm makes and breaks contact, substantially as set forth.

Eighteenth. The autograph telegraph comprising the combination of a series of transmitters and transmitting bristles or wires, a single main wire receivers corresponding in number to the transmitters, tuned to a pitch to vibrate in unison with the succession of electric impulses transmitted from their respective transmitters, vibratory circuit breakers, one for each receiver, and a local circuit and receiving bristle for each vibratory circuit breaker, the series of bristles resting upon prepared paper, the whole for operation substantially as shown and described.

In witness whereof, I, the said William Morgan-Brown, have hereunto set my hand and seal, this sixth day of June, in the year of our Lord One thousand eight hundred and seventy-seven.

WILLIAM MORGAN-BROWN (L. S.)

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A D. 1876. Dec. 9. N° 4765.
MORGAN-BROWN'S Specification

(3 SHEETS)
SHEET 1.

FIG. 1.

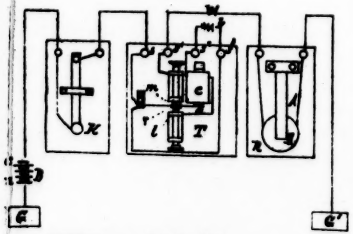


FIG. 2.

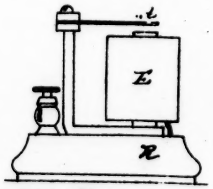


FIG. 27.

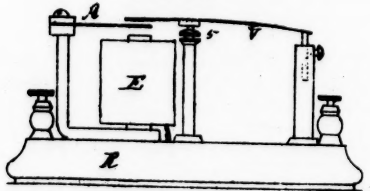


FIG. 20.

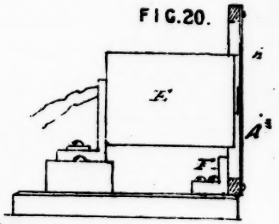


FIG. 28.

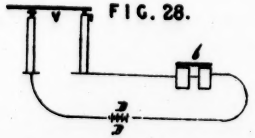


FIG. 29.

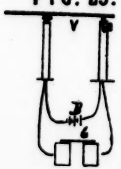
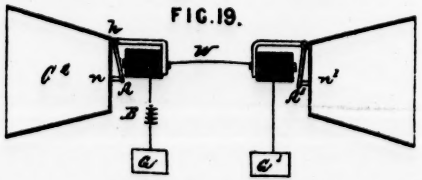


FIG. 15.

FIG. 19.



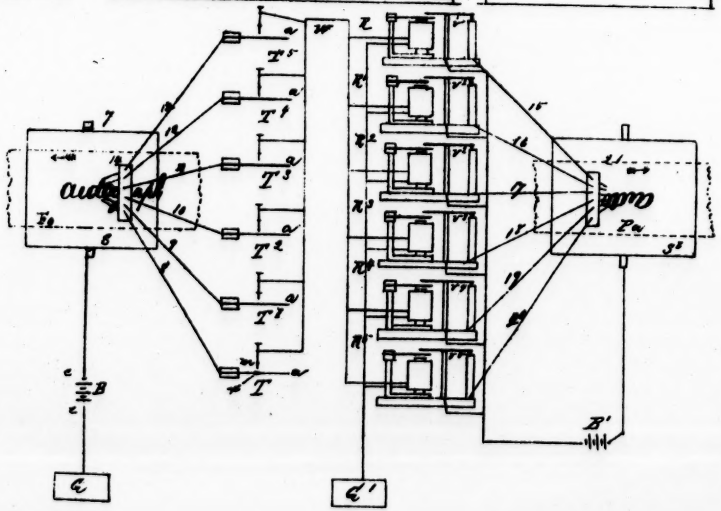


FIG. 7.

FIG. 6.
Direct

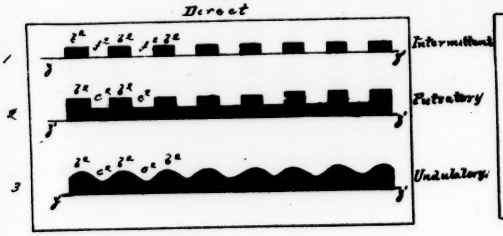


FIG. 7.
Reversed

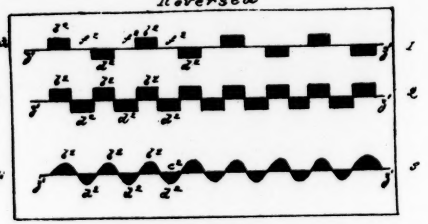


FIG. 11.

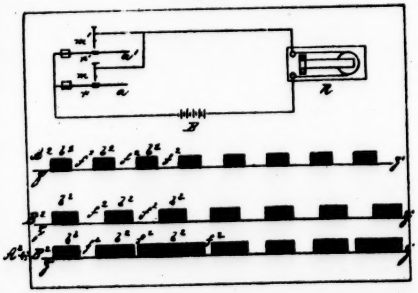


FIG 12.

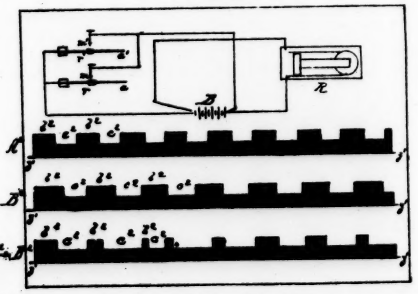


FIG. 13.

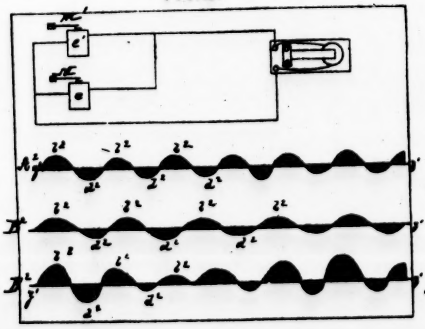
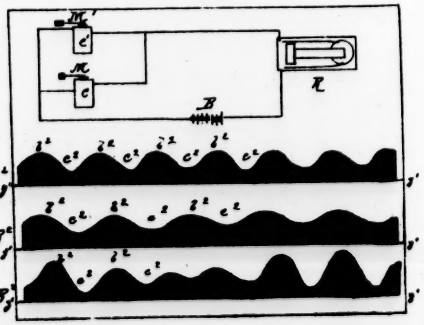


FIG. 14.



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A.D. 1876. Dec. 9. N° 4765.
MORGAN-BROWN'S Specification.

(3 SHEETS)
SHEET 2.

First Plan.

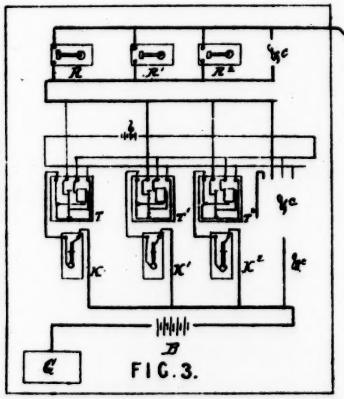
FIG. 3.

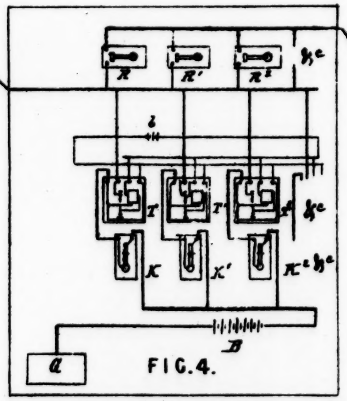
FIG. 4.

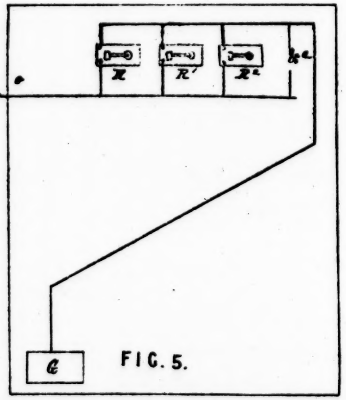
FIG. 5.

Second Plan.

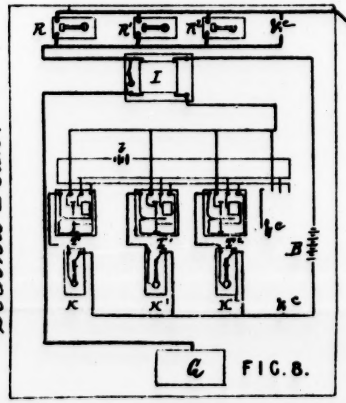
FIG. 8.

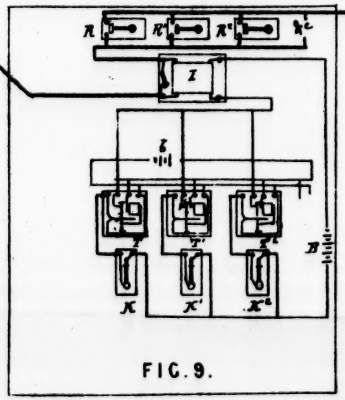
FIG. 9.

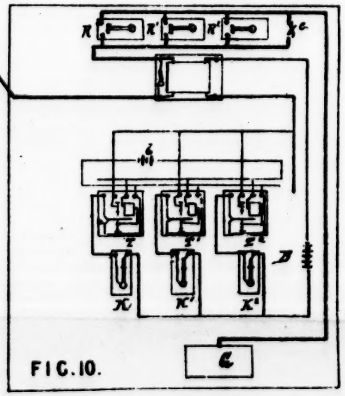
FIG. 10.

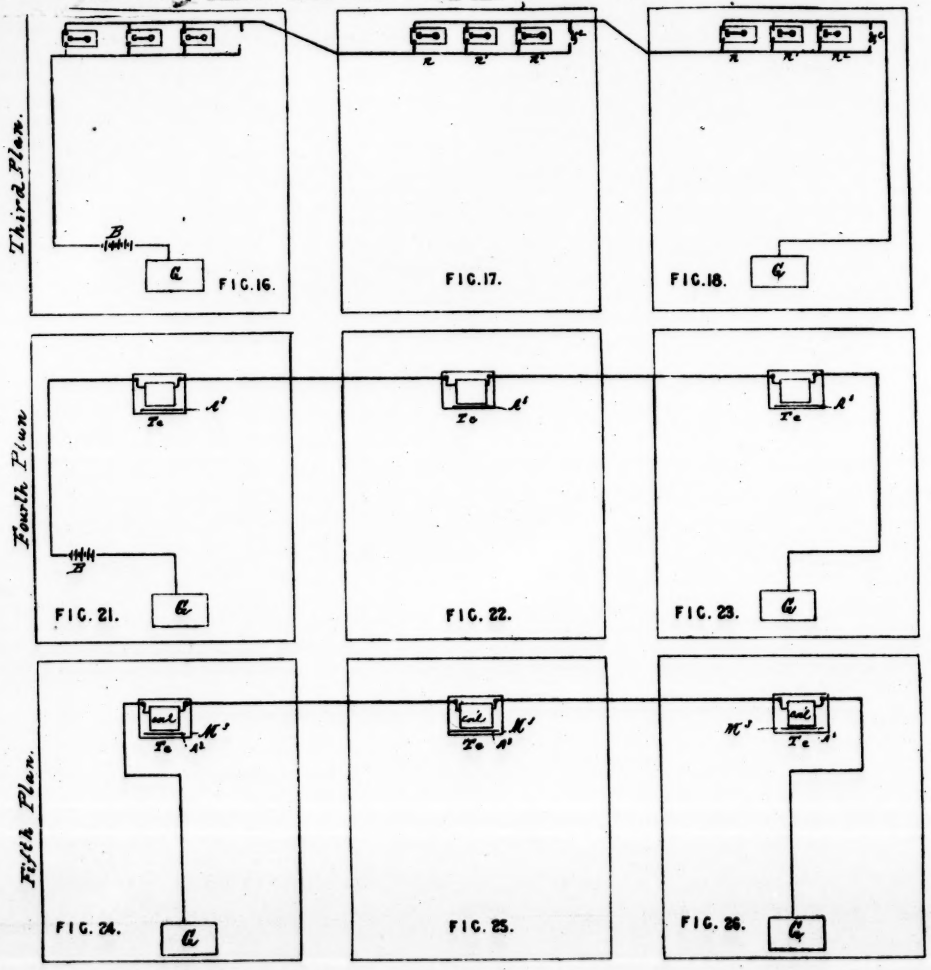
Third Plan.
B
G
FIG. 16.
FIG. 17.
FIG. 18.
Fourth Plan
B
G
FIG. 21.
FIG. 22.
FIG. 23.
Fifth Plan.
G
FIG. 24.
FIG. 25.
FIG. 26.

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FIG. 32.

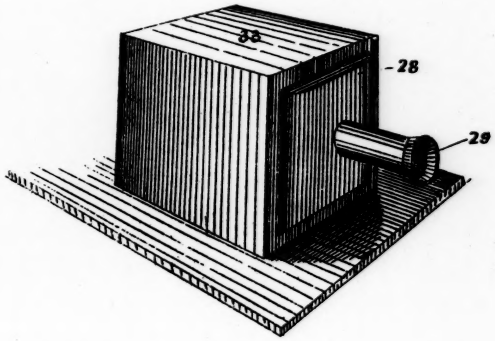
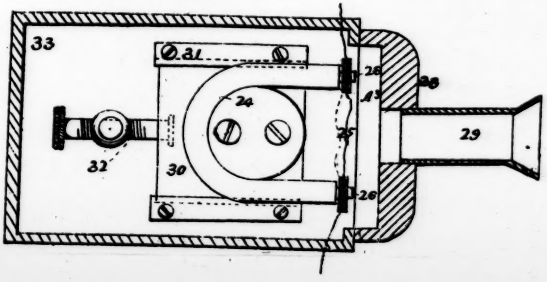


FIG. 31.



THURSDAY, May 28th, 1885.

OFFICE OF CHARLES HOWSON, ESQ.
119 South Fourth St.,
Philadelphia.

Parties meet pursuant to notice:

CHARLES HOWSON, ESQ.,
For Complainants.

FURMAN SHEPPARD, ESQ.,
For Respondants.

Counsel for complainants offers in evidence two several certified originals, and eight several certified copies, from the Patent Office of the United Kingdom of Great Britain and Ireland, of documents relating to British Patent No. 4765, dated December 9th, 1876, and granted to William Morgan-Brown for "improvements in electric telephony (transmitting or causing sounds for telegraphing messages) and telephonic apparatus," a communication to him from Alexander Graham Bell, of the University of Boston, Massachusetts, United States, each of said ten several instruments being certified by Henry Reader-Lack, Comptroller General of patents, designs and trade marks of the said United Kingdom of Great Britain and Ireland, and each having also annexed thereto the official certificates of Alfred Donnison, of the City of London, notary public, and of Lebbeus H. Mitchell, Vice and Deputy Consul-General of the United States for Great Britain and Ireland, at London; the said instruments being severally as follows:

A.—Copy of the petition of William Morgan-Brown, left, recorded and filed in the office of the Commissioners of Patents for Inventions, on the 9th day of December, 1876, and numbered 4765, together with the official endorsements thereon and now in the Patent Office of the United Kingdom of Great Britain and Ireland.

Marked Complainants' Exhibit "A" Samuel Bell, Special Examiner."

B.—Copy of the Statutory declaration left, filed and recorded in the Office of the Commissioners of Patents on the 9th day of December, A. D. 1876, in the matter of the Petition of William Morgan-Brown, numbered 4765.

Marked Complainants' Exhibit "B." Samuel Bell, Special Examiner.

C.—Copy of the amended declaration left, filed and recorded in the Office of the Commissioners of Patents on the 27th day of December, A. D. 1876, in the matter of the Petition of William Morgan-Brown, numbered 4765, left and filed in said Office on the 9th day of December, 1876,

Marked Complainants' Exhibit "C." Samuel Bell, Special Examiner.

C. C.—Copy of the Certificate of amendment of the Law Officer left, filed, and recorded in the Office of the Commissioners of Patents on the 27th day of December, 1876, in the matter of the Petition of William Morgan-Brown, which was numbered 4765 and filed in the said Office on the 9th day of December, 1876.

Marked Complainants' Exhibit "C. C." Samuel Bell, Special Examiner.

D.—Original certificate of allowance of provisional protection issued by the Commissioners of Patents for Inventions on the 27th day of December, 1876, in the matter of the Petition of William Morgan-Brown, numbered 4765, and left in the Office of said Commissioners on the 9th day of December, A. D. 1876.

Marked Complainants' Exhibit "D." Samuel Bell, Special Examiner.

E.—Copy of the notice of applicant's intention to proceed left, filed and recorded in the Office of the Commissioners of Patents, on the 8th day of February, 1877, in the matter of the petition of William Morgan-Brown, numbered 4765, and filed in said office on the 9th day of December, 1876, which said notice is now in the Patent Office of the United Kingdom of Great Britain and Ireland.

Marked Complainants' Exhibit "E." Samuel Bell, Special Examiner.

F.—Original certificate of the record of notice to proceed, issued by the Commissioners of Patents on the 8th day of February, A. D.

1877, in the matter of the petition of William Morgan-Brown, which was numbered 4765, and filed in said office on the 9th day of December, 1876.

Marked Complainants' Exhibit "F." Samuel Bell, Special Examiner.

I.—Copy of the original warrant of the law officer left with the Attorney General for signature, on May 8th, 1877, and on May 10th, 1877, received from him, and sealed, filed and recorded in the said Office, in the matter of the petition of William Morgan-Brown, numbered 4765, dated December 9th, 1876.

Marked Complainants' Exhibit "I." Samuel Bell, Special Examiner.

K.—Copy of Her Majesty's Royal letters Patent granted to William Morgan-Brown, for improvements in electric telephony (transmitting or causing sounds for telegraphic messages), and telephonic apparatus, sealed and granted May 15th, 1877, and dated December 9th, 1876.

Marked Complainants' Exhibit "K." Samuel Bell, Special Examiner.

L.—Copy of the Register of the Commissioners of Patents in the matter of the Petition of William Morgan-Brown, Numbered 4765, and filed December 9th, 1876, which said Register is now in the Patent Office of the United Kingdom of Great Britain and Ireland.

Marked Complainants' Exhibit "L" Samuel Bell Special Examiner.

Counsel for Respondents objects to the foregoing instruments of writing respectively, for the reasons, among others, that they are irrelevant, inadmissible, improperly, and insufficiently authenticated, and not legal or pertinent evidence as to any matter or thing in the cause.

It is agreed by Counsel for the respective parties that the original exhibits, referred to in the foregoing proffer, having been duly marked by the Special Examiner, may be retained by Complainants, and that printed copies thereof may be filed and used as evidence in the cause with the same force and effect as might the originals.

The originals to be produced for inspection at the hearing of the cause, if called for.

EXHIBIT "A."

I, ALFRED DONNISON, of the City of London, Notary Public, duly admitted and sworn, practising in the said City, *DO* hereby Certify and Attest:

That Henry Reader Lack, whose signature is subscribed at the foot of the Certificate hereunto annexed, marked "A," is the Comptroller-General of Patents, Designs, and Trade-Marks, that he is by law the custodian of the Record Papers and Documents, recorded, filed, and deposited in the Office of the Commissioners of Patents for inventions, and of the Patent Office of the United Kingdom of Great Britain and Ireland; that by the laws of England, and particularly by the Acts "15 and 16 Victoria, Chapter 83, Section II," and "16 and 17 Victoria, Chapter 115, Section IV," and "The Patent Designs and Trade-Marks Act, 1883, 46 and 47 Victoria, Chapter 57," copies of all such records, papers, and Documents certified by him and sealed with the Seal of The Patent Office, are to be received in evidence in all proceedings relating to Letters Patent for inventions in all Courts within the United Kingdom of Great Britain and Ireland without further proof or production of the originals.

And that the signature "H. Reader Lack" subscribed at the foot of the said annexed Certificate is truly that of the said Henry Reader Lack, Comptroller-General of Patents, Designs, and Trade-Marks, and the seal thereon impressed, is the genuine Seal of the Patent Office of the United Kingdom of Great Britain and Ireland, therefore full faith and credit should be given thereto in Judicature and thereout.

Whereof an Act being required, I, the said Notary, have granted these presents under my Notarial Firm and Seal to serve and avail when and where need may require.

Done and Passed in London the twelfth day of May, in the year of our Lord one thousand eight hundred and eighty-five.

{ NOTARIAL SEAL }

ALFRED DONNISON,
Not. Pub:

CONSULATE-GENERAL OF THE UNITED STATES OF AMERICA, LONDON.

I, LEBBEUS H. MITCHELL, Vice and Deputy Consul-General of the United States of America for Great Britain and Ireland, at London, do hereby make known and certify to all whom it may concern, that Alfred Donnison, who has signed the annexed Certificate, is a Notary Public, duly admitted and sworn, and practising in the City of London aforesaid, and that to all acts by him so done full faith and credit are and ought to be given in Judicature and thereout, and I further certify that the signature "H. Reader Lack" on the Certificate hereto annexed is the genuine signature of Henry Reader Lack, Comptroller-General of Patents, Designs, and Trade-Marks, and that the Seal thereon impressed is the genuine Seal of the Patent Office of the United Kingdom of Great Britain and Ireland.

In testimony whereof I have hereunto set my hand and affixed the Seal of the Consulate-General of the United States at London aforesaid, this twelfth day of May, in the year of our Lord one thousand eight hundred and eighty-five.

{SEAL OF UNITED STATES CONSULATE GENERAL, LONDON}

L. H. MITCHELL,
Vice and Deputy Consul-General.

PATENTS, DESIGNS AND TRADE MARKS ACT, 1883.

{ SEAL OF THE PATENT OFFICE } FORM Q.

"A"

Certificate of Comptroller-General.

PATENT OFFICE, LONDON, 11th May, 1885.

I, HENRY READER LACK, Comptroller-General of Patents, Designs, and Trade-Marks, hereby certify that the annexed paper, marked "A," is a true copy of the petition of William Morgan-Brown, left, recorded, and filed in the Office of the Commissioners of Patents for Inventions on the 9th day of December, 1876, and numbered 4765, together with the official endorsements thereon, and now in the Patent Office of the United Kingdom of Great Britain and Ireland.

In witness whereof I have hereunto set my hand, and caused the Seal of the Patent Office to be hereto affixed this eleventh day of May, one thousand eight hundred and eighty-five.

(E. T.) H. READER LACK.

To the Queen's Most Excellent Majesty:

"A"

9th December, 1876. 4765.

The humble Petition of William Morgan-Brown, of the firm of Brandon & Morgan-Brown, Engineers and Patent Agents, of 38 Southampton Buildings, London, and 1 Rue Laffitte, Paris, Sheweth,

That your Petitioner is in possession of an Invention for "Improvements in Electric Telephony (transmitting or causing sounds for telegraphing messages) and Telephonic Apparatus," which Invention he believes will be of great public utility; that it has been communicated to him from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology, and that the same is not in use by any other person or persons to the best of his knowledge and belief.

Your Petitioner therefore humbly prays that your Majesty will be pleased to grant unto him, his executors, administrators, and assigns Your Royal Letters Patent for the United Kingdom of Great Britain and Ireland, the Channel Islands, and the Isle of Man for the term of fourteen years, pursuant to the Statutes in that case made and provided.

And Your Petitioner
Will ever pray, etc.

13th Dec., 1876.

Her Majesty is pleased to refer this Petition to Her Majesty's Attorney-General to consider what may be properly done therein.

H. READER LACK,
Clerk of the Commissioners.

8th March, 1877.

Her Majesty is pleased again to refer this Petition to Her Majesty's Attorney-General to consider what may be properly done therein.

H. READER LACK,
Clerk to the Commissioners.

Let a warrant be prepared for my signature upon the within Petition, limited to the United Kingdom of Great Britain and Ireland, the Channel Islands, and the Isle of Man.

(Ex'd G. S.) JOHN HOLKER,
8th March, 1877.

(Endorsed.) "A."

No. 4765–76.

PETITION.

Fo. 6. 2 /.

EXHIBIT "B."

[Similar certificates (bearing the same date) as to Exhibit "A," by Alfred Donnison, Notary Public, and Lebbeus H. Mitchell, Vice and Deputy Consul-General of the United States of America for Great Britain and Ireland, at London.]

PATENTS, DESIGNS AND TRADE MARKS ACT, 1883.

{ SEAL OF THE PATENT OFFICE } FORM Q. "B."

Certificate of Comptroller-General.

PATENT OFFICE, LONDON, 11th May, 1885.

I, HENRY READER LACK, Comptroller-General of Patents, Designs, and Trade-Marks, hereby certify that the annexed paper, marked "B," is a true Copy of the Statutory declaration left, filed, and recorded in the Office of the Commissioners of Patents on the 9th day of December, A. D. 1876, in the matter of the Petition of William Morgan-Brown, Numbered 4,765, left and filed in the said Office at the same time, which said Declaration is now in the Patent Office of the United Kingdom of Great Britain and Ireland.

In witness whereof I have hereto set my hand and caused the Seal of the Patent Office to be hereto affixed, this eleventh day of May, 1885.

E. T. H. READER LACK.

9 Dec. 1876. 4765. "B."

I, William Morgan-Brown, of the Firm of Brandon and Morgan-Brown, Engineers and Patent Agents, of 38 Southampton Buildings, London, and 1 Rue Laffitte, Paris, Do solemnly and sincerely declare that I am in possession of an Invention for Improvements in Electric Telephony (transmitting or causing sounds for telegraphing messages) and Telephonic apparatus, which Invention I believe will be of great public utility; that it has been communicated to me from

abroad by Alexander Graham Bell, of Edinburgh, Scotland, now of the University of Boston, Massachusetts, Professor of Vocal Physiology, and that the same is not in use by any other Person or Persons to the best of my knowledge and belief, and I make this solemn Declaration conscientiously believing the same to be true, and by virtue of the provisions of an Act made and passed in the Session of Parliament held in the fifth and sixth years of the Reign of His late Majesty King William the Fourth, intituled "An Act to repeal an "Act of the present Session of Parliament intituled an Act for the "more effectual abolition of Oaths and Affirmations taken and made "in various Departments of the State, and to substitute Declarations "in lieu thereof, and for the more entire suppression of voluntary and "extra-judicial oaths and affidavits, and to make other provisions for "the abolition of unnecessary oaths."

William Morgan-Brown Declared at No. 38 Southampton Buildings, Chancery Lane, in the County of Middlesex, this eighth day of December, in the year of our Lord 1876, before me,

JOSH. I. HARLOW,

A Commissioner to administer oaths in the Supreme Court of Judicature.

(Ex'd G. S.)

(Endorsed.) **"B."**

No. 4765–76.

DECLARATION (Originally filed).

Fo. 6. 2 /.

EXHIBIT "C."

[Similar certificates (bearing the same date) as to Exhibit "A," by Alfred Donnison, Notary Public, and Lebbeus H. Mitchell, Vice and Deputy Consul-General of the United States of America for Great Britain and Ireland, at London.]

PATENTS, DESIGNS AND TRADE MARKS ACT, 1883.

{ SEAL OF THE PATENT OFFICE } FORM Q. "C."

Certificate of Comptroller-General.

PATENT OFFICE, LONDON, 11th May, 1885.

I, HENRY READER LACK, Comptroller-General of Patents, Designs, and Trade-Marks, hereby certify that the annexed paper, marked "C," is a true copy of the amended declaration left, filed, and recorded in the Office of the Commissioner of Patents, on the 27th day of December, A. D. 1876, in the matter of the Petition of William Morgan-Brown, numbered 4765, left and filed in said Office on the 9th day of December, 1876, which said amended declaration is now in the Patent Office of the United Kingdom of Great Britain and Ireland.

In witness whereof, I have hereunto set my hand, and caused the Seal of the Patent Office to be hereto affixed, the 11th day of May, one thousand eight hundred and eighty-five.

(E. T.) H. READER LACK.

{ SEAL OF THE PATENT OFFICE } A. J. H. "C."

I, William Morgan-Brown, of the Firm of Brandon & Morgan-Brown, Engineers and Patent Agents, of 38 Southampton Buildings, London, and 1 Rue Laffitte, Paris, Do solemnly and sincerely declare that I am in possession of an Invention for Improvements in Electric Telephony (transmitting or causing sounds for telegraphing

messages) and Telephonic Apparatus, which Invention I believe will be of great public utility; that it has been communicated to me from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology, and that the same is not in use by any other Person or Persons, to the best of my knowledge and belief, and I make this solemn Declaration, conscientiously believing the same to be true; and by virtue of the provisions of an Act made and passed in the Session of Parliament, held in the fifth and sixth years of the Reign of His late Majesty, King William the Fourth, intituled "An "Act to repeal an Act of the present session of Parliament, intituled "an Act for the more effectual abolition of Oaths and Affirmations "taken and made in various Departments of the State, and to substi- "tute Declarations in lieu thereof, and for the more entire suppres- "sion of voluntary and extra-judicial oaths and affidavits, and to "make other provisions for the abolition of unnecessary oaths."

William Morgan Brown. Declared at No. 39 Southampton Buildings, Chancery Lane, in the County of Middlesex, this twentieth day of December, in the year of our Lord, 1876, Before me, Josh. I. Harlow, a Commissioner to administer oaths in the Supreme Court of Judicature.

(Ex'd G. S.)

(Endorsed.) **"C."**

No. 4765–76.

AMENDED DECLARATION.

Fo. 6. 2/

EXHIBIT "C. C."

[Similar certificates (bearing the same date) as to Exhibit "A," by Alfred Donnison, Notary Public, and Lebbeus H. Mitchell, Vice and Deputy Consul-General of the United States of America for Great Britain and Ireland, at London.]

PATENTS, DESIGNS AND TRADE MARKS ACT, 1883.

{ SEAL OF THE PATENT OFFICE } FORM Q. **"C. C."**

Certificate of Comptroller-General.

PATENT OFFICE, LONDON, 11th May, 1885.

I, HENRY READER LACK, Comptroller-General of Patents, Designs, and Trade Marks, hereby certify That the paper annexed, marked "C. C.," is a true copy of the Certificate of Amendment of the Law Officer left, filed and recorded in the Office of the Commissioners of Patents, on the 27th day of December, 1876, in the matter of the Petition of William Morgan-Brown, which was numbered 4765, and filed in the said Office on the 9th day of December, 1876, which certificate is now in the Patent Office of the United Kingdom of Great Britain and Ireland.

In witness whereof, I have hereunto set my hand, and caused the Seal of the Patent Office to be hereto affixed, this 11th day of May, one thousand eight hundred and eighty-five.

H. READER LACK.

(E. T.)

{ SEAL OF THE PATENT OFFICE }

"C. C."

PATENT LAW AMENDMENT ACT, 1852.

4765.

Petition of William Morgan-Brown of the firm of Brandon and Morgan-Brown, Engineers and Patent Agents, of 38 Southampton Buildings, London, and 1 Rue Lafitte, Paris, for a Patent for Improvements in electric telephony (transmitting or causing sounds for telegraphing messages) and telephone apparatus.

Communicated to him from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology.

Whereas the Declaration and the Petition are insufficient, I hereby allow the same to be amended by adding to the Documents the new Declaration, marked "A," annexed hereto, and correcting the petition in accordance therewith, to which amendments I have placed my initials.

JOHN HOLKER.

(Ex'd G. S.) 23d December, 1876.

(Endorsed.) "C. C."

No. 4765–76.

AMENDMENT OF LAW OFFICER.

Fo. 3. 1/

EXHIBIT "D."

[Similar certificates (bearing the same date) as to Exhibit "A," by Alfred Donnison, Notary Public, and Lebbeus H. Mitchell, Vice and Deputy Consul-General of the United States of America for Great Britain and Ireland, at London.]

PATENTS, DESIGNS AND TRADE MARKS ACT, 1883.

{ SEAL OF THE PATENT OFFICE } FORM Q. **"D."**

Certificate of Comptroller-General.

PATENT OFFICE, LONDON, 11th May, 1885.

I, HENRY READER LACK, Comptroller-General of Patents, Designs, and Trade-Marks, hereby certify That the annexed paper, marked "D," is the original certificate of allowance of provisional protection, issued by the Commissioners of Patents for Inventions, on the 27th day of December, 1876, in the matter of the Petition of William Morgan-Brown, numbered 4765, and left in the office of said Commissioners on the 9th day of December, A. D. 1876.

In witness whereof I have hereunto set my hand and caused the Seal of the Patent Office to be hereto affixed this 11th day of May, one thousand eight hundred and eighty-five.

(E. T.) H. READER LACK.

PATENT LAW AMENDMENT ACT, 1852.

"D."

OFFICE OF THE COMMISSIONERS OF PATENTS FOR INVENTIONS.

Dec., 1876, 4765.
Brandon.

{ SEAL OF THE PATENT OFFICE }

THIS IS TO CERTIFY that Provisional Protection has been allowed to William Morgan-Brown, of the firm of Brandon & Morgan-Brown, Engineers and Patent Agents, of 38 Southampton Buildings, London, and 1 Rue Laffitte, Paris, for the Invention of "Improvements in electric telephony (transmitting or causing sounds for telegraphing messages) and telephonic apparatus," a communication to him from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology, on his Petition, recorded in the Office of the Commissioners, on the 9th day of Decr., 1876.

{ SEAL OF THE COMMISSIONERS OF PATENTS FOR INVENTIONS }

N. B.—Notice to proceed hereon must be left at the above Office, *eight weeks at the least* before the expiration of the term of Provisional Protection.

Application for the Warrant and Letters Patent must be made *twelve clear*, i. e., *fourteen days at the least*, before the expiration of the term of Provisional Protection.

No Money received after Three o'Clock—Saturdays, Two o'Clock.

(Endorsed.) "D."

EXHIBIT "E."

[Similar certificates (bearing the same date) as to Exhibit "A," by Alfred Donnison, Notary Public, and Lebbeus H. Mitchell, Vice and Deputy Consul-General of the United States of America for Great Britain and Ireland, at London.]

PATENTS, DESIGNS AND TRADE MARKS ACT, 1883.

{ SEAL OF THE PATENT OFFICE } FORM Q. "E"

Certificate of Comptroller-General.

(E. T.) PATENT OFFICE, LONDON, 11th May, 1885.

I, HENRY READER LACK, Comptroller-General of Patents, Designs, and Trade marks, hereby certify That the annexed paper marked "E," is a true copy of the Notice of applicant's intention to proceed left, filed, and recorded in the Office of the Commissioners of Patents on the 8th day of February, 1877, in the matter of the Petition of William Morgan-Brown, numbered 4765 and filed in said Office on the 9th day of December, 1876, which said notice is now in the Patent Office of the United Kingdom of Great Britain and Ireland.

In witness whereof I have hereunto set my hand, and caused the Seal of the Patent Office to be hereto affixed this 11th day of May, one thousand eight hundred and eighty-five. H. READER LACK.

(E. T.)

4675 76.

PATENT LAW AMENDMENT ACT, 1852. "E."

{ SEAL OF THE PATENT OFFICE }

We, Brandon and Morgan-Brown, Agents for William Morgan-Brown, of the firm of Brandon and Morgan-Brown, Engineers and Patent Agents, of 38 Southampton Buildings, London, and 1 Rue Lafitte, Paris, Do hereby give notice, that it is my intention to proceed on behalf of the said William Morgan-Brown, with his application for Letters Patent, for the Invention of "Improvements in electric telephony (transmitting or causing sounds for telegraphing messages) and telephonic apparatus." A communication to him from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology, as set forth in his Petition, recorded in the Office of the Commissioners of Patents for Inventions, on the 9th day of December, 1876.

Dated this 8th day of February, 1877.

(Ex'd G. S.) BRANDON & MORGAN-BROWN,
Agents.

ENDORSED "E."

No. 4765–76.

NOTICE TO PROCEED.

Fo. 3. 1/.

EXHIBIT "F."

[Similar certificates (bearing the same date) as to Exhibit "A," by Alfred Donnison, Notary Public, and Lebbeus H. Mitchell, Vice and Deputy Consul-General of the United States of America for Great Britain and Ireland, at London.]

PATENTS, DESIGNS AND TRADE MARKS ACT, 1883.

{ SEAL OF THE PATENT OFFICE } FORM Q. "F."

Certificate of Comptroller-General.

PATENT OFFICE, LONDON, 11th May, 1885.

I, HENRY READER LACK, Comptroller-General of Patents, Designs, and Trade-Marks, hereby certify, That the annexed paper, marked "F," is the original certificate of the record of notice to proceed, issued by the Commissioners of Patents on the 8th day of February, A. D. 1877, in the matter of the Petition of William Morgan-Brown, which was numbered 4765, and filed in said Office on the 9th day of December, 1876.

In witness whereof, I have hereunto set my hand, and caused the Seal of the Patent Office to be hereto affixed, this 11th day of May, one thousand eight hundred and eighty-five.

E. T. H. READER LACK.

PATENT LAW AMENDMENT ACT, 1852.

4765. Brandon. £. 5.

{ SEAL OF THE PATENT OFFICE } "F."

THIS IS TO CERTIFY, that William Morgan-Brown, of the firm of Brandon and Morgan-Brown, Engineers and Patent Agents, of 38 Southampton Buildings, London, and 1 Rue Laffitte, Paris, has given notice of his intention to proceed with his application for Letters Patent, for the Invention of "Improvements in Electric Telephony (transmitting or causing sounds for telegraphing messages) and telephonic apparatus." A communication to him from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology, as set forth in his Petition, recorded in the Office of the Commissioners of Patents for Inventions, on the 9th day of December, 1876, and the Stamp Duty of Five Pounds has been paid on this Certificate, pursuant to the Act.

Dated this 8th day of February, 1877.

{ SEAL OF THE COMMISSIONERS OF PATENTS FOR INVENTIONS }

N. B.—Application for the Warrant and Letters Patent must be made *twelve clear days* (*i.e., fourteen*) *at the least* before the expiration of the term of Provisional Protection.

No money received after Three o'clock—Saturdays, Two o'clock.

(ENDORSED) "F."

EXHIBIT "I."

[Similar certificates (bearing the same date) as to Exhibit "A," by Alfred Donnison, Notary Public, and Lebbeus H. Mitchell, Vice and Deputy Consul-General of the United States of America for Great Britain and Ireland, at London.]

PATENTS, DESIGNS AND TRADE MARKS ACT, 1883.

{ SEAL OF THE PATENT OFFICE } FORM Q. "I."

Certificate of Comptroller-General.

PATENT OFFICE, LONDON, 11th May, 1885.

I, HENRY READER LACK, Comptroller-General of Patents, Designs, and Trade-Marks, hereby certify, That the annexed paper, marked "I," is a true copy of the original warrant of the law officer left with the attorney-general for signature on May 8th, 1877, and on May 10th, 1877, received from him, and sealed, filed, and recorded in the said office, in the matter of the petition of William Morgan-Brown, numbered 4765, dated December 9th, 1876, which said original Warrant is now in the Patent Office of the United Kingdom of Great Britain and Ireland.

In witness whereof I have hereunto set my hand, and caused the Seal of the Patent Office to be hereto affixed this 11th day of May, one thousand eight hundred and eighty-five.

(E. T.) H. READER LACK.

Received the 15th day of May, 1877. CAIRNS C.
1876. No. 4765.

{ SEAL OF THE PATENT OFFICE } "I."

To the Right Honorable, the Lord High Chancellor of Great Britain:

In humble Obedience to Her Majesty's command, referring to me the Petition of William Morgan-Brown, of the firm of Brandon and Morgan-Brown, Engineers and Patent Agents, of 38 South-

ampton Buildings, London, and 1 Rue Laffitte, Paris, to consider what may be properly done therein, I do hereby certify as follows: That the said Petition sets forth that the Petitioner is in possession of an Invention for "Improvements in Electric Telephony (transmitting or causing sounds for telegraphing messages) and Telephonic apparatus." And the Petitioner most humbly prays that Her Majesty will be pleased to grant to him, his executors, administrators, and assigns, Her Majesty's Royal Letters Patent for the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man for the term of Fourteen years, pursuant to the Statute in that case made and provided, That in support of the allegations contained in the said Petition, the Declaration of the Petitioner has been laid before me, whereby he solemnly declares that he is in possession of the said Invention; that he believes the same will be of great public utility; that the said Invention has been communicated to him from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology; and that the same is not in use by any other person or persons to the best of his knowledge and belief; That there has also been laid before me the Provisional Specifications of the said Petitioner, and also a certificate whereby it appears that the said Invention was provisionally protected from the ninth day of December, one thousand eight hundred and seventy-six in pursuance of the Statute. Upon consideration of all the matters aforesaid, and as it is entirely at the hazard of the said Petitioner whether the said Invention is new or will have the desired success, and as it may be reasonable for Her Majesty to encourage all Arts and Inventions which may be for the public good, I am of opinion that Her Majesty may grant Her Royal Letters Patent unto the Petitioner, his executors, administrators and assigns, for the said Invention within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man for the term of fourteen years, according to the Statute in that case made and provided, if Her Majesty shall be graciously pleased so to do to the tenor and effect following:

Victoria, by the Grace of God of the United Kingdom of Great Britain and Ireland, Queen, Defender of the Faith. To all to whom these Presents shall come, Greeting: Whereas, William Morgan-Brown, of the firm of Brandon and Morgan-Brown, Engineers and Patent Agents of 38 Southampton Buildings, London, and 1 Rue Laffitte, Paris, hath by his Petition humbly represented unto us that

he is in possession of an Invention for "Improvements in Electric Telephony (transmitting or causing sounds for telegraphing messages) and Telephonic Apparatus," which the Petitioner believes will be of great public utility; that the said Invention has been communicated to him from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology; and that the same is not in use by any other person or persons to the best of his knowledge and belief. The Petitioner therefore most humbly prayed that We would be graciously pleased to grant unto him, his executors, administrators and assigns, Our Royal Letters Patent for the sole use, benefit and advantage of the said Invention within Our United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, for the term of Fourteen years, pursuant to the Statute in that case made and provided. And we being willing to give encouragement to all Arts and Inventions which may be for the public good, are graciously pleased to condescend to the Petitioner's request. Know ye therefore, that We of Our especial grace, certain knowledge, and mere motion, Have given and granted, and by these Presents for Us, Our heirs, and successors, Do give and grant unto the said William Morgan-Brown, his executors, administrators, and assigns, Our especial license, full power, sole privilege and authority, that he, the said William Morgan-Brown, his executors, and administrators and assigns, and every of them by himself and themselves or by his and their Deputy or Deputies, Servants or Agents or such others as he, the said William Morgan-Brown, his executors, administrators or assigns shall at any time agree with, and no others, from time to time, and at all times hereafter during the term of years herein expressed, shall and lawfully may make, use, exercise, and vend the said Invention within Our United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, in such manner as to him, the said William Morgan-Brown, his executors, administrators, and assigns or any of them shall in his or their discretion seem meet. And that he, the said William Morgan-Brown, his executors, administrators, and assigns shall and lawfully may have and enjoy the whole profit, benefit, commodity, and advantage from time to time, coming, growing, accruing, and arising by reason of the said Invention for and during the term of years herein mentioned. To have, hold, exercise, and enjoy the said licenses, powers, privileges, and advantages hereinbefore granted or mentioned to be granted unto

the said William Morgan-Brown, his executors, administrators, and assigns for and during and unto the full end and term of Fourteen years from the day of the date of these Presents next and immediately ensuing, according to the Statute in such case made and provided. And to the end that he, the said William Morgan-Brown, his executors, administrators, and assigns and every of them may have and enjoy the full benefit and the sole use and exercise of the said Invention according to Our gracious intention hereinbefore declared, We do by these Presents for Us, Our heirs, and successors require and strictly command all and every person and persons, bodies, politic and corporate, and all other Our subjects whatsoever, of what estate, quality, degree, name or condition soever they be within Our United Kingdom of Great Britain and Ireland, the Channel Islands, and the Isle of Man, that neither they nor any of them at any time during the continuance of the said term of Fourteen years, hereby granted either directly or indirectly, do make use or put in practice the said Invention or any part of the same so attained unto by the said William Morgan-Brown as aforesaid, nor in anywise counterfeit, imitate or resemble the same, nor shall make or cause to be made any addition thereunto or subtraction from the same whereby to pretend himself or themselves the Inventor or Inventors, Devisor or Devisors thereof, without the consent, license or agreement of the said William Morgan-Brown, his executors, administrators, or assigns in writing under his or their hands and seals first had and obtained in that behalf upon such pains and penalties as can or may be justly inflicted on such Offenders for their contempt of this Our Royal Command. And further to be answerable to the said William Morgan-Brown, his executors, administrators, and assigns according to Law for his and their damages thereby occasioned. And moreover, We do by these Presents for Us, Our heirs, and successors Will and Command all and singular the Justices of the Peace, Mayors, Sheriffs, Bailiffs, Constables, Headboroughs, and all other Officers and Ministers whatsoever of Us, Our heirs, and successors for the time being that they or any of them do not nor shall at any time during the said term hereby granted in anywise molest, trouble, or hinder the said William Morgan-Brown, his executors, administrators or assigns or any of them or his or their Deputies, Servants or Agents in or about the due and lawful use or exercise of the aforesaid Invention or anything relating thereto.

Provided, always, And these Our Letters Patent are and shall be upon this condition, that if at any time during the said term hereby granted, it shall be made, appear to Us, Our heirs or successors or any six or more of Our or their Privy Council that this Our Grant is contrary to Law or prejudicial or inconvenient to Our Subjects in general, or that the said Invention is not a new Invention as to the public use and exercise thereof within Our United Kingdom of Great Britain and Ireland, the Channel Islands and Isle of Man, or that the same was not first introduced therein by the said William Morgan-Brown as aforesaid, these Our Letters Patent shall forthwith cease, determine, and be utterly void to all intents and purposes, anything herein before contained to the contrary thereof in anywise notwithstanding. Provided also that these Our Letters Patent or anything herein contained shall not extend or be construed to extend to give privilege unto the said William Morgan-Brown, his executors, administrators or assigns or any of them to use or imitate any Invention or Work whatsoever which hath heretofore been found out or invented by any other of Our Subjects whatsoever, and publicly used or exercised within Our United Kingdom of Great Britain and Ireland, the Channel Islands, or Isle of Man, unto whom Our like Letters Patent or Privileges have been already granted for the sole use, exercise and benefit thereof. It being Our Will and Pleasure that the said William Morgan-Brown, his executors, administrators and assigns and all and every other person and persons to whom like Letters Patent or Privileges have been already granted as aforesaid shall distinctly use and practise their several Inventions by them invented and found out according to the true intent and meaning of the same respective Letters Patent, and of these Presents. Provided, likewise, nevertheless, and these Our Letters Patent are upon this express condition, that if the said William Morgan-Brown, his executors or administrators shall not particularly describe and ascertain the nature of the said Invention, and in what manner the same is to be performed by an Instrument in writing under his or their or one of their hands and seals and cause the same to be filed in the Great Seal Patent Office within Six calendar Months next and immediately after the date of these our Letters Patent; And also, if the said William Morgan-Brown, his executors, administrators or assigns shall not pay the Stamp Duty of Fifty Pounds, and produce these Our Letters Patent stamped with a proper stamp to that amount at the Office of Our Commissioners of Patents for Inventions

before the expiration of Three Years from the date of these Our Letters Patent, pursuant to the provisions of the Act of the Sixteenth Year of Our Reign, Chapter 5, and also if the said William Morgan-Brown, his executors, administrators or assigns shall not pay the Stamp Duty of One Hundred Pounds and produce these our Letters Patent, stamped with a proper stamp to that amount at the said Office of Our said Commissioners before the expiration of Seven years from the date of these Our Letters Patent pursuant also to the said Act; And also if the said William Morgan-Brown, his executors, administrators or assigns shall not supply or cause to be supplied for Our service all such Articles of the said Invention as he or they shall be required to supply by the Officers or Commissioners administering the department of Our Service, for the use of which the same shall be required in such manner at such times and at and upon such reasonable prices and terms as shall be settled for that purpose by the said Officers or Commissioners requiring the same; That then and in any of the said cases these Our Letters Patent and all liberties and advantages whatsoever hereby granted, shall utterly cease, determine and become void, anything hereinbefore contained to the contrary thereof in anywise notwithstanding. Provided that nothing herein contained shall prevent the granting of Licenses in such manner and for such considerations as they may by Law be granted. And lastly, We do by these Presents for Us, Our heirs and successors grant unto the said William Morgan-Brown, his executors, administrators, and assigns that these Our Letters Patent or the filing thereof shall be in and by all things good, firm, valid, sufficient and effectual in the Law, according to the true intent and meaning thereof, and shall be taken, construed and adjudged in the most favorable and beneficial sense for the best advantage of the said William Morgan-Brown, his executors, administrators, and assigns as well in all Our Courts of Record as elsewhere, and by all and singular, the Officers and Ministers whatsoever of Us, Our heirs and successors in Our United Kingdom of Great Britain and Ireland, the Channel Islands and Isle of Man, and amongst all and every the subjects of Us, Our heirs and successors whatsoever and wheresoever, Notwithstanding the not full and certain describing the nature or quality of the said Invention or of the materials thereunto conducing and belonging. In witness whereof We have caused these Our Letters to be made Patent this ninth day of December, One thousand eight hundred and seventy-six, in the fortieth year of Our

Reign, and to be sealed as of the said ninth day of December, One thousand eight hundred and seventy-six.

Given under my hand this eighth day of May, One thousand eight hundred and seventy-seven.

JOHN HOLKER.

I hereby certify that the Letters Patent issued upon the within written Warrant were produced and registered at the Office of the Commissioners of Patents for Inventions on this 28th day of November, 1879, properly stamped with a Stamp Duty of Fifty pounds, pursuant to the Act 16, Vic: C. 5.

H. READER LACK,
Clerk of the Commissioners.

I hereby certify that the Letters Patent issued upon the within written Warrant were produced and registered at the Office of the Commissioners of Patents for Inventions on this 30th day of Nov., 1883, properly stamped with a Stamp Duty of One Hundred pounds, pursuant to the Act 16, Vic. c. 5.

H. READER LACK,
Clerk of the Commissioners.

(Ex'd G. S.)

(ENDORSED) "I."

No. 4765–76.

WARRANT.

Fo. 27. 9/.

EXHIBIT "K."

[Similar certificates (bearing the same date) as to Exhibit "A," by Alfred Donnison, Notary Public, and Lebbeus H. Mitchell, Vice and Deputy Consul-General of the United States of America for Great Britain and Ireland, at London.]

PATENTS, DESIGNS AND TRADE MARKS ACT, 1883.

{ SEAL OF THE PATENT OFFICE } FORM Q.

"K."

Certificate of Comptroller-General.

PATENT OFFICE, LONDON, 11th May, 1885.

I, HENRY READER LACK, Comptroller-General of Patents, Designs, and Trade-Marks, hereby certify, That the annexed paper, marked "K," is a true copy of Her Majesty's Royal Letters Patent granted to William Morgan-Brown, for "Improvements in Electric Telephony (transmitting or causing sounds for telegraphic messages) and telephonic apparatus," sealed and granted May 15th, 1877, and dated December 9th, 1876.

In witness whereof, I have hereunto set my hand, and caused the Seal of the Patent Office to be hereto affixed, this 11th day of May, one thousand eight hundred and eighty-five.

(E. T.) H. READER LACK.

1876.

No. 4765. "K."

{ SEAL OF THE PATENT OFFICE }

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland, Queen, Defender of the Faith. To all to whom these Presents shall come, Greeting: Whereas, William Morgan-Brown, of the firm of Brandon and Morgan-Brown, Engineers and patent agents of 38 Southampton Buildings, London, and 1 Rue Laffitte, Paris, hath by his Petition humbly represented unto Us that

he is in possession of an Invention for "Improvements in Electric Telephony (transmitting or causing sounds for telegraphing messages) and Telephonic apparatus," which the Petitioner believes will be of great public utility; that the said Invention has been communicated to him from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology, and that the same is not in use by any other person or persons to the best of his knowledge and belief. The Petitioner therefore most humbly prayed that We would be graciously pleased to grant unto him, his executors, administrators, and assigns, Our Royal Letters Patent for the sole use, benefit, and advantage of the said Invention within Our United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, for the term of Fourteen Years, pursuant to the Statute in that case made and provided; And We being willing to give encouragement to all Arts and Inventions which may be for the public good, are graciously pleased to condescend to the Petitioner's request. Know Ye, therefore, that We, of Our especial grace, certain knowledge and mere motion, Have given and granted and by These Presents for Us, our heirs, and successors, Do give and grant unto the said William Morgan-Brown, his executors, administrators, and assigns, Our special license, full power, sole privilege, and authority, that he, the said William Morgan-Brown, his executors, administrators, and assigns, and every of them, by himself and themselves, or by his and their Deputy or Deputies, Servants, or Agents, or such others as he, the said William Morgan-Brown, his executors, administrators, or assigns, shall at any time agree with, and no others, from time to time, and at all times hereafter, during the term of years herein expressed, shall and lawfully may make, use, exercise, and vend the said Invention within our United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, in such manner as to him, the said William Morgan-Brown, his executors, administrators, and assigns, or any of them, shall in his or their discretion seem meet. And that he, the said William Morgan-Brown, his executors, administrators, and assigns, shall and lawfully may have and enjoy the whole profit, benefit, commodity, and advantage from time to time, coming, growing, accruing, and arising by reason of the said Invention for and during the term of years herein mentioned, To have, hold, exercise, and enjoy the said licenses, powers, privileges, and advantages hereinbefore granted or mentioned to be granted unto the said

William Morgan-Brown, his executors, administrators, and assigns, for and during and unto the full end and term of Fourteen Years from the day of the date of these Presents next and immediately ensuing, according to the Statute in such case made and provided. And to the end, that the said William Morgan-Brown, his executors, administrators, and assigns, and every of them, may have and enjoy the full benefit and the sole use and exercise of the said Invention, according to Our gracious intention hereinbefore declared, We do by these Presents, for Us, Our heirs, and successors, require and strictly command all and every person and persons, bodies politic and corporate, and all other Our subjects whatsoever of what estate, quality, degree, name, or condition soever they be within Our United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, that neither they nor any of them at any time during the continuance of the said term of Fourteen Years hereby granted, either directly or indirectly do make, use, or put in practice the said Invention or any part of the same so attained unto by the said William Morgan-Brown as aforesaid, nor in anywise counterfeit, imitate, or resemble the same, nor shall make or cause to be made any addition thereunto, or subtraction from the same, whereby to pretend himself or themselves, the Inventor or Inventors, Devisor or Devisors thereof without the consent, license, or agreement of the said William Morgan-Brown, his executors, administrators, or assigns, in writing under his or their hands and seals, first had and obtained in that behalf upon such pains and penalties as can or may be justly inflicted on such offenders for their contempt of this Our Royal Command. And further, to be answerable to the said William Morgan-Brown, his executors, administrators, and assigns, according to law for his and their damages thereby occasioned. And, moreover, We do by these Presents for Us, Our heirs and Successors, Will and Command all and singular the Justices of the Peace, Mayors, Sheriffs, Bailiffs, Constables, Headboroughs, and all other Officers and Ministers whatsoever of Us, Our heirs, and successors for the time being, that they or any of them do not, nor shall at any time during the said term hereby granted in any wise molest, trouble, or hinder the said William Morgan-Brown, his executors, administrators, or assigns, or any of them or his or their Deputies, Servants, or Agents, in or about the due and lawful use or exercise of the aforesaid Invention, or anything relating thereto; Provided, always, and these our Letters Patent are, and shall be upon this Condition, that if at any time during the said

term hereby granted it shall be made appear to Us, Our heirs, or successors, or any six or more of our or their Privy Council that this our grant is contrary to Law, or prejudicial or inconvenient to Our Subjects in general, or that the said Invention is not a new Invention as to the public use and exercise thereof within Our United Kingdom of Great Britain and Ireland, the Channel Islands, and the Isle of Man, or that the same was not first introduced therein by the said William Morgan-Brown as aforesaid, these Our Letters Patent shall forthwith cease, determine, and be utterly void to all intents and purposes, anything hereinbefore contained to the contrary thereof in anywise notwithstanding. Provided, also, that these our Letters Patent or anything herein contained shall not extend or be construed to extend to give privilege unto the said William Morgan-Brown, his executors, administrators, or assigns, or any of them, to use or imitate any Invention or Work whatsoever which hath heretofore been found out or invented by any other of Our Subjects whatsoever, and publicly used or exercised within Our United Kingdom of Great Britain and Ireland, the Channel Islands, or Isle of Man, unto whom Our like Letters Patent or Privileges have been already granted for the sole use, exercise, and benefit thereof. It being Our Will and Pleasure that the said William Morgan-Brown, his executors, administrators, and assigns, and all and every other person and persons to whom like Letters Patent or Privileges have been already granted as aforesaid shall distinctly use and practice their several Inventions by them invented and found out according to the true intent and meaning of the same respective Letters Patent and of these Presents. Provided, Likewise, nevertheless, And these our Letters Patent are upon this express Condition, that if the said William Morgan-Brown, his executors, or administrators, shall not particularly describe and ascertain the nature of the said Invention, and in what manner the same is to be performed by an Instrument in writing, under his or their, or one of their hands and seals, and cause the same to be filed in the Great Seal Patent Office within Six Calendar Months next, and immediately after the date of these Our Letters Patent; And also if the said William Morgan-Brown, his executors, administrators, or assigns, shall not pay the Stamp Duty of Fifty Pounds and produce these Our Letters Patent stamped with a proper Stamp to that amount at the Office of Our Commissioners of Patents for Inventions before the expiration of Three Years from the date of these Our Letters Patent, pursuant to the provisions of the Act of the Sixteenth

year of Our Reign, Chapter 5. And also if the said William Morgan-Brown, his executors, administrators, or assigns, shall not pay the Stamp duty of One hundred Pounds and produce these Our Letters Patent stamped with a proper Stamp to that amount at the said Office of Our said Commissioners before the expiration of Seven Years from the date of these Our Letters Patent, pursuant also to the said Act; And also, if the said William Morgan-Brown, his executors administrators, or assigns, shall not supply or cause to be supplied for Our Service all such Articles of the said Invention as he or they shall be required to supply by the Officers or Commissioners administering the Department of Our Service, for the use of which the same shall be required in such manner, at such times, and at and upon such reasonable prices and terms as shall be settled for that purpose by the said Officers or Commissioners requiring the same; That then and in any of the said cases these Our Letters Patent and all liberties and advantages whatsoever hereby granted, shall utterly cease, determine, and become void, anything hereinbefore contained to the contrary thereof in anywise notwithstanding. Provided, That nothing herein contained shall prevent the granting of Licenses in such manner and for such considerations as they may by Law be granted. And Lastly, We do by these presents, for Us, Our heirs and successors, grant unto the said William Morgan-Brown, his executors, administrators, and assigns, that these Our Letters Patent or the filing thereof shall be in and by all things good, firm, valid, sufficient, and effectual in the Law according to the true intent and meaning thereof, and shall be taken, construed, and adjudged in the most favourable and beneficial sense for the best advantage of the said William Morgan-Brown, his executors, administrators, and assigns, as well in all Our Courts of Record as elsewhere, and by all and singular the Officers and Ministers whatsoever of Us, Our heirs and successors in Our United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, and amongst all and every the Subjects of Us, Our heirs and successors, whatsoever and wheresover, Notwithstanding the not full and certain describing the nature or quality of the said Invention or of the materials thereunto conducing and belonging. In witness whereof, We have caused these Our Letters to be made Patent this ninth day of December, one thousand eight hundred and seventy-six, in the fortieth year of Our Reign, and to be sealed as of the said ninth day of December, one thousand eight hundred and seventy-six.

By Warrant.

I hereby Certify, that the within-written Letters Patent were produced and registered at the Office of the Commissioners of Patents for Inventions on this 28th day of November, 1879, properly stamped with a Stamp Duty of Fifty Pounds, pursuant to the Act 16 Vic, c. 5.

H. READER LACK,
Clerk of the Commissioners.

I hereby Certify that the within Letters Patent were produced and registered at the Office of the Commissioners of Patents for Inventions on this 30th day of November, 1883, properly stamped with a Stamp Duty of One Hundred pounds, pursuant to the Act 16 Vic. c. 5.

H. READER LACK,
Clerk of Commissioners.

(Ex'd G. S.)

(ENDORSED) "K."

No. 4765-76.

LETTERS PATENT.

Fo. 22. 7/4.

EXHIBIT "L."

[Similar certificates (bearing the same date) as to Exhibit "A," by Alfred Donnison, Notary Public, and Lebbeus H. Mitchell, Vice and Deputy Consul-General of the United States of America for Great Britain and Ireland, at London.]

PATENTS, DESIGNS AND TRADE MARKS ACT, 1883.

FORM Q.

"L."

Certificate of Comptroller-General.

PATENT OFFICE, LONDON, 11th May, 1885.

I, HENRY READER LACK, Comptroller-General of Patents, Designs, and Trade-Marks, hereby certify that the annexed paper, marked "L," is a true Copy of the Register of the Commissioners of Patents in the matter of the Petition of William Morgan-Brown, Numbered 4765, and filed December 9th, 1876, which said Register is now in the Patent Office of the United Kingdom of Great Britain and Ireland.

In witness whereof I have hereto set my hand, and caused the Seal of the Patent Office to be hereto affixed this 11th day of May, 1885.

(E. T.) H. READER LACK.

{ SEAL OF THE PATENT OFFICE }

REGISTER OF PATENTS. "L."

9th December, 1876, Petition, Declaration, and Provisional Specification of

4765 WILLIAM MORGAN-BROWN, of the Firm of Brandon & Morgan-Brown, Engineers and Patent Agents, of 38 Southampton Buildings, London, and 1 Rue Laffitte, Paris, for grant of Letters Patent for an invention for Improvements in electric telephony (transmitting or causing sounds for telegraphing messages) and telephonic apparatus.

A communication to him from abroad by Alexander Graham Bell, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology.

Sealed with the Commissioners' Seal and referred to Attorney-General.

13th December, Petition, declaration, and provisional specification left with Attorney-General for allowance.

27th December, Certificate of Attorney-General allowing provisional protection with new Declaration added, received, and filed, and Certificate thereof given.

5th January, 1877, Provisional protection advertised in Gazette.

8th February, Notice to proceed received and filed, and Certificate thereof given.

13th February, Notice to proceed advertised in Gazette.

8th March, Petition, declaration, and provisional specification again referred to Attorney-General.

12th March, Fiat for warrant received.

8th May, Warrant left with Attorney-General for signature.

10th May, Warrant received, sealed, and filed.

15th May, Letters Patent prepared, sealed, and dated the 9th December, 1876.

9th June, Specification filed in pursuance of Letters Patent.

25th January, 1878, Petition presented by William Morgan-Brown (Patentee) praying leave to file Disclaimer and Memorandum of Alteration.

28th January, Petition and Disclaimer left with Attorney-General.

13th February, Fiat received, and Disclaimer and Memorandum of Alteration filed.

14th June, Agreement—Morgan-Brown & ors. with Cox-Book, R. 4, pa. 396.

25th November, Assignment—Morgan-Brown to The Telephone Cy., Ld., Book, U. 4, pa. 214.

28th November, 1879, Letters Patent stamped with £50 stamp, produced at Office of Commissioners of Patents, and Certificate thereof endorsed thereon.

27th May, 1880, Agreement—The Telephone Coy., Limd., with Tracy & anor. Book E, 5, pa. 73.

23d July, Assignment—The Edison Telephone Company, of London, Limd., to The United Telephone Company, Limd. Book E 5, pa. 511.

11th September, Assignment—The Telephone Coy., Limd. to The United Telephone Compy., Limd. Book F 5, pa. 455.

15th February, 1883, Agreement—The United Telephone Coy., Limd., & Ors. with the National Telephone Coy., Limd. Book Y 5, pa. 356.

30th November, Letters Patent stamped with £100 Stamp, produced at Office of Commissioners of Patents, and Certificate thereof endorsed thereon.

25th July, 1884, By request received and filed, The United Telephone Co., Limited, of Oxford Court, Cannon Street, London, registered as entitled to an Assignment. Agreement—The Telephone Co., Limited, and The Edison Telephone Co., Limited, with the United Telephone Compy., Limited, produced, and Copy thereof filed.

(Ex'd G. S.)

(ENDORSED) "L."

No. 4765–76.

REGISTER.

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ARTICLES OFFERED BY COUNSEL FOR COMPLAINANT.

EXHIBIT "HUGHES MAY 9, 1878, ARTICLE."

From Scientific American, Supplement, for June 8, 1878.

[READ BEFORE THE ROYAL SOCIETY, LONDON, MAY 9, 1878.]

ON THE ACTION OF SONOROUS VIBRATIONS IN VARYING THE FORCE OF AN ELECTRIC CURRENT.

BY PROF. D. E. HUGHES.

COMMUNICATED BY PROF. HUXLEY, F. R. S., &c. RECEIVED MAY 8, 1878.

The introduction of the telephone has tended to develop our knowledge of acoustics with great rapidity. It offers to us an instrument of great delicacy for further research into the mysteries of acoustic phenomena. It detects the presence of currents of electricity that have hitherto only been suspected, and it shows variations in the strengths of currents which no other instrument has ever indicated.

It has led me to investigate the effect of sonorous vibrations upon the electrical behavior of matter. Willoughby Smith has shown that the resistance of selenium is affected by light, and Bornstein has led us to believe that many other bodies are similarly affected. We know also that the resistance of all bodies is materially influenced by heat. Sir William Thomson and others have shown that the resistance to the passage of currents offered by wires is affected by their being placed under strains, and, inasmuch as the conveyance of sonorous vibrations induces rapid variations in the strains at different points of a wire, I believed that the wire would vary in its resistance when it was used to convey sound. To investigate this, I made a rough-and-ready telephone, with a small bar magnet four inches long, half the coil of an ordinary electro-magnet, and a square piece of ferrotype iron, three inches square, clamped rigidly in front of one pole of the magnet, between two pieces of board. When using the pendulum beats of a small French clock, or the voice, as a source of sound, I found this arrangement supplied me with an extremely delicate *phonoscope*, or sound detector.

All the experiments detailed in this paper were made with the

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Under such conditions the willow carbon will be found to be metallized, having the metal distributed throughout its pores in a fine state of division. Iron also seems to enter the pores, if heated to a white heat without being chemically combined with the carbon as in graphite, and indeed some of the best results have been obtained from willow charcoal, containing iron in a fine state of division.

Pine charcoal, treated in this manner (although a non-conductor as a simple charcoal), has high conductive powers, due to the iron, and from the minute division of the iron in the pores is a most excellent material for the purpose.

Any one of these preparations, combined in a glass tube or a box, and provided with wires for insertion in a circuit, I call a "transmitter."

Reis, in 1860, showed how, by the movement of a diaphragm, intermittent voltaic currents could be transmitted, agreeing in exact number with the sonorous waves impinging on the diaphragm, and thus reproducing music at a distance, by causing an electro-magnet to vibrate in unison with the diaphragm; and with an iron diaphragm, Graham Bell showed how the vibrations of that diaphragm in front of a polarized electro-magnet could similarly induce magneto-currents, corresponding in number, amplitude, and form with the sonorous vibration, and thus reproduce all the delicacies of the human voice. Edison and others have produced variations in the strengths of a constant current, by causing the diaphragm to press directly upon some elastic conductor, such as carbon, spongy platinum, &c., the varying pressure upon these materials varying the resistance of the circuit, and consequently the strength of current flowing. Graham Bell and others have produced the same effect, by causing the vibrations of the diaphragm to vary the electro-motive force in the circuit. It will be seen, however, that in the experiments made by myself the diaphragm has been altogether discarded, resting as it does upon the changes produced by molecular action, and that the variations in the strengths of the currents flowing are produced simply and solely by the direct effect of the sonorous vibrations.

I have found that any sound, however feeble, produces vibrations which can be taken up by the matter interposed in the electrical circuit. Sounds absolutely inaudible to the human ear affect the resistance of the conductors described above. In practice, the effect is so sensitive that a slight touch on the board by the finger nail, on which the transmitter is placed, or a mere touch with the soft part of a feather, would be distinctly heard at the receiving station. The movement

of the softest camel hair brush on any part of the board is distinctly audible. If held in the hand several feet from a piano, the whole chords—the highest as well as the lowest—can be distinctly heard at a distance. If one person sings a song, the distant station, provided with a similar transmitter, can speak and sing at the same time, and the sounds will be received loud enough for the person singing to follow the second speech or song sent from the distant end.

Acting on these facts, I have also devised an instrument suitable for magnifying weak sounds, which I call a *microphone*. The microphone, in its present form, consists simply of a lozenge-shaped piece of gas carbon, one inch long, quarter inch wide at its centre, and one-eighth of an inch in thickness. The lower pointed end rests as a pivot upon a small block of similar carbon; the upper end, being made round, plays free in a hole in a small carbon block, similar to that at the lower end. The lozenge stands vertically upon its lower support. The whole of the gas carbon is tempered in mercury, in the way previously described, though this is not absolutely necessary. The form of the lozenge-shaped carbon is not of importance, provided the weight of this upright contact piece is only just sufficent to make a feeble contact by its own weight. Carbon is used in preference to any other material, as its surface does not oxidize. A platinum surface in a finely divided state is equal, if not superior, to the mercurized carbon, but more difficult and costly to construct. I have also made very sensitive ones entirely of iron.

The best form and materials for this instrument, however, have not yet been fully experimented on. Still, in its present shape, it is capable of detecting very faint sounds made in its presence. If a pin, for instance, be laid upon or taken off a table, a distinct sound is emitted, or if a fly be confined under a table-glass, we can hear the fly walking, with a peculiar tramp of its own. The beating of a pulse, the tick of a watch, the tramp of a fly, can thus be heard at least a hundred miles distant from the source of sound. In fact, when further developed by study, we may fairly look for it to do for us, with regard to faint sounds, what the microscope does with matter too small for human vision.

It is quite evident that these effects are due to a difference of pressure at the different points of contact, and that they are dependent for the perfection of action upon the number of these points of contact. Moreover, they are not dependent upon any apparent difference in the bodies in contact, but the same body, in a state of minute

subdivision, is equally effective. Electrical resistance is a function of the mass of the conductor, but sonorous conduction is a function of the molecules of matter. How is it, therefore, that a sonorous wave can so affect the mass of a conductor as to influence its electrical resistance? If we assume a line of molecules, we know that a sonorous wave is accompanied by alternate compressions and rarefactions. If we isolate the part under compression from the part under dilatation, we vary the dimensions of the mass, and we alter its electrical resistance. In any homogeneous conductor of finite dimensions, the effect of the one will exactly compensate for the effect of the other, and we get no variation of current; but if we break up this homogeneous conductor into a series of minute subdivisions, without actually breaking their electrical continuity, we destroy this neutralizing influence, and we render evident the effect of sonorous vibrations in varying the dimensions of the mass of the conductor, and therefore in varying its electrical resistance, for we reduce the length of a portion of the conductor to a fraction of the length of a sonorous wave. Molecular action, alone, explains to me all the effects produced. Size or shape does not effect them. A piece of willow charcoal the size of a pin's head is quite sufficient to produce articulate speech. I regard the action as follows: If we have two separate conductors, joined simply by contact, this contact offers a certain resistance. Now, we can vary or lessen the resistance by increasing the pressure, thus bringing more points in contact, or closer proximity. Now, as I employ a constant pressure on the contact, which is exactly under the same influence of the vibrations as the points of contact, more points, or closer proximity, can only be obtained through the molecular swelling or movement of the contact points.

If we assume a line of molecules at the point of contact of the minute masses of conducting matter in their neutral condition to be arranged thus, **OOOOO** They will appear thus under compression, **OOOOO** and thus under dilatation, OOOOO In the former case the electrical resistance would be *less*, and in the latter case *more*, than in the normal condition. Hence we should get variation in their electrical resistance, and thus sonorous waves could vary the strength of an electric current, and the variations of the electric current can be made to reproduce sonorous vibrations. These, however, would only produce the result in a certain line, say horizontal; but those perpendicular, while producing the same result, would be a half vibration behind, and thus if two contacts, the one horizontal and the other perpendicular, were on the same piece of charcoal, and the

conducting line joined to both, we should have interference. The contrary takes place, as the more contacts we have, and the more varied their direction on the same, the louder and purer the sound becomes. Hence there is no interference, and consequently the whole mass must swell and diminish equally in all directions at the same instant of time.

The tube transmitter, which I exhibit this evening, consists of an exterior glass tube two inches long and one-quarter of an inch in diameter. In it are four separate pieces of willow charcoal, each one-quarter of an inch long, and two terminals of the same material. The terminals are fastened in the tube, and connect exteriorly with the line and interiorly with the four loose pieces, thus:—

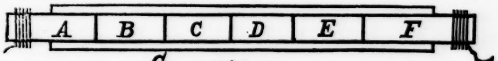

Fig. 2.

Here A is made to press on B, C, D, E, and F, until the resistance offered to the electrical current is about one-third that of the line upon which it is to be employed. It may be attached to a resonant board by the ends A or F. If the result was simply due to vibrations, we should have A and B making greater contact at a different time from E and F, and consequent interference. If it was a simple shaking or moving of B, C, D, E, and F, it could produce no change, as, if B pressed more strongly on C, it would be less on A, and also if the tube was attached by the centre we should have no effect; but if the effect is due to a swelling or enlargement of B, C, D, E, F, it would make no difference where it is attached to the resonant board, as is actually the case. Again, reduce the pressure of A upon B, &c., until they are not in contact, and no trace of current can be perceived by shaking the tube. The instant the sonorous vibrations pass in the tube there is electric contact to a remarkable degree, which could only have taken place by the molecules enlarging their sphere under the influence of the sonorous vibrations.

It is impossible to say what can be the applications of the effects of the discovery which I have had the honor of bringing before the Royal Society, for the whole question has been studied with crude materials, and scarcely sufficient time has elapsed to enable me to consider its ultimate uses. I do not desire to assert that there is anything in what I have brought forward that is superior to or equal to other transmitters used for telephony. It is as loud and far more sensitive than any I have yet heard, and it may be increased by multiplication of

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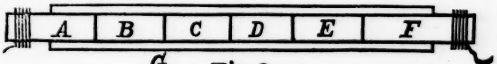

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transmitting contacts in quantity or intensity; the loudness is at present limited by the capability of the receiver. The materials at my disposal, and the arrangement of them, have not yet been sufficiently studied. I only wished to show that it is possible to transmit clear and intelligent articulate speech, and to render audible sounds which have hitherto been inaudible, by the mere operation of sonorous vibrations upon the conducting power of matter. My warmest thanks are due to Mr. W. H. Preece, electrician to the Post Office, for his appreciation of the importance of the facts I have stated, and for his kind counsel and aid in the preparation of this paper.

I do not intend to take out a patent, as the facts I have mentioned belong more to the domain of discovery than invention. No doubt inventors will ere long improve on the form and materials employed. I have already my reward in being allowed to submit my researches to the Royal Society.

COMPLAINANTS' EXHIBIT "HUGHES JUNE 8, 1878, ARTICLE."

From The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, Vol. VI., Fifth Series, July, 1878, pp. 44-50.

ON THE PHYSICAL ACTION OF THE MICROPHONE.*

BY PROFESSOR HUGHES.

In the paper read on the 9th of May, before the Royal Society, I gave a general outline of the discoveries I had made, the materials used, and the forms of microphone employed in demonstrating important points. I have made a great number of microphones, each for some special purpose, varying in form, mechanical arrangement, and materials. It would require too much time to describe even a few of them, and as I am anxious in this paper to confine myself to general considerations, I will take it for granted that some of the forms of instrument and the results produced are already known.

The problem which the microphone solves is this: To introduce into an electrical circuit an electrical resistance, which resistance shall vary in exact accord with sonorous vibrations so as to produce an undulatory current of electricity from a constant source, whose wavelength, height, and form shall be an exact representation of the sonorous waves. In the microphone we have an electric conducting material susceptible of being influenced by sonorous vibrations, and thus we have the first step of the problem.

* Communicated by the Physical Society, having been read June 8, 1878.

The second step is one of the highest importance. It is essential that the electrical current flowing be thrown into waves of determinate form, by the sole action of the sonorous vibrations. I resolved this by the discovery that when an electric conducting matter in a divided state, either in the form of powder, filings, or surfaces, is put under a certain slight pressure, far less than that which would produce cohesion and more than would allow it to be separated by sonorous vibrations, the following state of things occurs. The molecules at these surfaces being in a comparatively free state, although electrically joined, do of themselves so arrange their form, their number in contact, or their pressure (by increased size or orbit of revolution), that the increase and decrease of electrical resistance of the circuit is altered in a very remarkable manner, so much so as to be almost fabulous.

The problem being solved, it is only necessary to observe certain general considerations to produce an endless variety of microphones, each having a special range of resistance.

The tramp of a fly or the cry of an insect requires little range, but great sensitiveness; and two surfaces, therefore, of chosen materials under a very slight pressure, such as the mere weight of a small superposed conductor, suffice; but it would be unsuitable for a man's voice, as the vibrations would be too powerful, and would, in fact, go so far beyond the legitimate range, that interruptions of contact amounting to the well-known "make and break" would be produced.

A man's voice requires four surfaces of pine charcoal, as is described in my paper to the Royal Society, six of willow charcoal, eight of boxwood, and ten of gas carbon. The effects, however, are far superior with the four of pine, than with either the ten of gas carbon or any other material, as yet used. It should be noted that pine wood is the best resonant material we possess; and it preserves its structure and quality, when converted into the peculiar charcoal I have discovered and described.

It is not only necessary to vary the number of surfaces and materials, in accordance with the range and power of the vibrations, but these surfaces and materials must be put under more or less pressure, in accordance with the force of the sonorous vibrations. Thus for a man's voice, the surfaces must be under a far greater pressure than for the movements of insects. Still, the range of useful effect is very great, as the boxes which I have specially arranged for a man's voice are still sensitive to the tick of a watch.

In all cases it should be so arranged that a perfect undulatory current is obtained from the sonorous vibrations of a certain range.

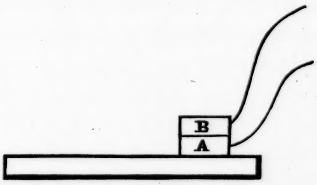
Thus, when speaking to a microphone transmitter of human speech, a galvanometer should be placed in the circuit, and, while speaking, the needle should not be deflected, as the waves of + and — electricity are equal, and are too rapid to disturb the needle, which can only indicate a general weakening or strengthening of the current. If the pressure on the materials is not sufficient, we shall have a constant succession of interruptions of contact, and the galvanometer needle will indicate the fact. If the pressure on the materials is gradually increased, the tones will be loud but wanting in distinctness, the galvanometer indicating interruptions; as the pressure is still increased, the tone becomes clearer, and the galvanometer will be stationary when a maximum of loudness and clearness is attained. If the pressure be further increased, the sounds become weaker, though very clear; and as the pressure is still further augmented, the sounds die out (as if the speaker were talking and walking away at the same time), until a point is arrived at where there is complete silence.

When the microphone is fixed to a resonant board, the lower contact should be fixed to the board, so that the sonorous vibrations act directly on it. The upper contact, where the pressure is applied, should be as free as possible from the influence of the vibrations, except those directly transmitted to it by the surfaces underneath; it (the upper surface) should have its inertia supplemented by that of a balance weight. This inertia I find necessary, to keep the contact unbroken by powerful vibrations. No spring can supply the required inertia; but an adjustable spring may be used to insure that the comparatively heavy lever shall duly press on the contacts.

The superposed surfaces in contact may be screwed down by an insulated screw passing through them all, thus doing away with the lever and spring; but this arrangement is far more difficult to adjust, and the expansion by heat of the screw causes a varying pressure. It is exceedingly simple, however, easily made, and illustrates the theoretical conditions better than the balanced lever I have adopted in practice.

In order to study the theoretical considerations, and that with the most simple form of microphone, freed from all surrounding mechanisms, let us take a flat piece of charcoal two millimetres thick and one centimetre square, and after making electrical contact by means of a copper wire on the lower surface, glue that to a small resonant board or better for the purpose of observation, to a block of wood ten centimetres square. Upon this superpose one or more similar blocks of charcoal, the upper surface in communication with a wire,

the lowermost surface resting flat, or as nearly so as possible, on the lower block. The required pressure is put on the upper block; and while in this state the two may be fastened together with glue at the sides, or, better, by an insulated screw. The pressure can then be removed, as the screw or glue equally preserves the force. Let the lower piece be called A, and the upper B; when we subject this board to sonorous vibrations, we cannot imagine an undulatory movement of the actual wave-length in such a mass, that is a length comparable with the real wave-length of the sonorous wave, which may be several feet. Nor can we imagine a wave of any length, without admitting that the force must be transmitted from molecule to molecule throughout the entire length; thus any portion of a wave, of which this block represents a fraction, must be in molecular activity.



The lower portion of the charcoal A, being part of the block itself, has this molecular action throughout, transmitting it also to the upper block. How is it that the molecular action at the surfaces of A and B should so vary the conductivity or electrical resistance as to throw it into waves in the exact form of the sonorous vibrations? It cannot be because it throws up the upper portion, making an intermittent current, because the upper portion is fastened to the lower, and the galvanometer does not indicate any interruption of current whatever. It cannot be because the molecules arrange themselves in stratified lines, becoming more or less conductive, as then surfaces would not be required; that is, we should not require discontinuity between the blocks A and B; nor would the upper surface be thrown up if the pressure be removed, as sand is on a vibrating glass. The throwing up of this upper piece B, when pressure is removed, proves that a blow, pressure, or upheaval of the lower portion takes place; that this takes place there cannot be any doubt, as the surface, considered alone (having no depth), could not bodily quit its mass. In fact, there must have been a movement to a certain depth; and I am inclined to believe, from numerous experiments, that the whole block increases and diminishes in size at all points, in the centre as well as the surface, exactly in accordance with the form of the sonorous wave. Confining our attention, however, to points on A and B, how can this increased molecular size or form produce a change in the electrical waves? This may happen in two ways: *first*, by increased pressure on the upper surface, due to its

enlargement; or, *second*, the molecules themselves, finding a certain resistance opposed to their upward movement, spread themselves, making innumerable fresh points of contact. Thus an undulatory current would appear to be produced by infinite change in the number of fresh contacts. I am inclined to believe that both actions occur, but the latter seems to me the true explanation, for if the first were alone true, we should have a far greater effect from metal powder, carbon, or some elastic conductor, such as metallized silk, than from gold, or other hard, unoxidizable matter; but, as the best results as regards the human voice were obtained from two surfaces of solid gold, I am inclined to view with more favor the idea that an infinite variety of fresh contacts brought into play by the molecular pressure, affords the true explanation. It has the advantage of being supported by the numerous forms of microphone I have constructed, in all of which I can fully trace the effect.

I have been very much struck by the great mechanical force exerted by this uprising of the molecules under sonorous vibrations. With vibrations from a musical box two feet in length, I found that one ounce of lead was not sufficient on a surface of contact one centimetre square to maintain constant contact; and it was only by removing the musical box to a distance of several feet, that I was enabled to preserve continuity of current with a moderate pressure. I have spoken to forty microphones at once, and they all seemed to respond with equal force. Of course there must be a loss of energy in the conversion of molecular vibrations into electrical waves; but it is so small that I have never been able to measure it with the simple appliances at my disposal. I have examined every portion of my room —wood, stone, metal, in fact, all parts—and even a piece of India-rubber: all were in molecular movement whenever I spoke. As yet I have found no such insulator for sound as gutta percha is for electricity. Caoutchouc seems to be the best; but I have never been able, by the use of any amount at my disposal, to prevent the microphone reporting all it heard.

The question of insulation has now become one of necessity, as the microphone has opened to us a world of sounds, of the existence of which we were unaware. If we can insulate the instrument so as to direct its powers on any single object, as at present I am able to do on a moving fly, it will be possible to investigate that object undisturbed by the pandemonium of sounds which at present the microphone reveals where we thought complete silence prevailed.

I have recently made the following curious observation. A micro-

phone on a resonant board is placed in a battery-circuit, together with two telephones. When one of these is placed on the resonant board, a continuous sound will emanate from the other. The sound is started by the vibration which is imparted to the board when the telephone is placed on it; this impulse, passing through the microphone, sets both telephone-discs in motion; and the instrument on the board, reacting through the microphone, causes a continuous sound to be produced, which is permanent so long as the independent current of electricity is maintained through the microphone. It follows that the question of providing a *relay* for the human voice in telephony is thus solved.

The transmission of sound through the microphone is perfectly duplex; for if two correspondents use microphones as transmitters and telephones as receivers, each can hear the other, but his own speech is inaudible; and if each sing a different note, no chord is heard. The experiments on the deaf have proved that they can be made to hear the tick of a watch, but not, as yet, human speech distinctly; and my results in this direction point to the conclusion that we only hear ourselves speak through the bones and not through the ears.

However simple the microphone may appear at first glance, it has taken me many months of unremitting labor and study, to bring it to its present state through the numerous forms, each suitable for a special object. The field of usefulness for it widens every day. Sir Henry Thompson has succeeded in applying it to surgical operations of great delicacy, and by its means splinters, bullets, in fact all foreign matter, can be at once detected. Dr. Richardson and myself have been experimenting in lung and heart diseases; and, although the application by Sir H. Thompson is more successful, I do not doubt that we shall ultimately succeed. There is also hope that deafness may be relieved. For telephony articulation has become perfect, and the loudness increased. Duplex and multiplex telegraphy will profit by its use, and there is hardly a science where acoustics has any direct or indirect relation which will not be benefited. And I feel happy in being able to present this paper on the results obtained by a purely physical action to such an appropriate and appreciative body as the Physical Society.

In conclusion, allow me to state that throughout the whole of my investigations I have used Professor Bell's wonderfully sensitive telephone instrument as a receiver, and that it is owing to the discovery of so admirable an appliance that I have been enabled to commence and follow up my researches.

MONDAY, April 13, 1885.

Met pursuant to notice at 11 o'clock A. M., at Dr. Charles M. Cresson's office, 417 Walnut street, in the city of Philadelphia.

Present: FURMAN SHEPPARD, ESQ., *Counsel for Respondents.*
E. N. DICKERSON, ESQ., *Counsel for Complainants.*

Dr. Charles M. Cresson, a witness produced on behalf of respondents, being duly affirmed, deposes and says as follows:—

Q 1. What is your name, age, place of business, and profession?

A. Charles M. Cresson; I am in the fifty-eighth year of my age; by profession an analytical chemist and expert in physics, and have followed this profession during a period of over thirty-three years; my place of business is at No. 417 Walnut street, Philadelphia.

Q 2. What experience have you had in the investigation of electrical devices, and what opportunities of gaining information in telegraphy and telephony?

A. I have frequently been employed in the construction and examination of various devices for electrical telegraphy and kindred purposes. My first knowledge of the electrical telegraph was acquired at the meetings of the Committee on Science and the Arts of the Franklin Institute, of which my father was for many years the chairman. An exhibition of the electrical telegraph was made before that committee, at a meeting when I was present, by Professor Morse, in the year 1838, and it was followed in succeeding years by other telegraphic exhibits, including the chemical and type telegraphs of Bain, House, and others.

Models of these various sorts of telegraphs, and of other electrical devices (such as those of Professor Robert Hare and Professor Page and Joseph Saxton), were used as illustrations at the lectures at the Franklin Institute, at which lectures I was an assistant, and took part in the preparation of the apparatus used in illustration, and in this way I became familiar with the practical manipulations required by each.

During the years from 1857 until 1876 I had occasion to repeat many of the experiments described by Professor Michael Faraday in his work entitled "Experimental Researches in Electricity." I refer chiefly to those upon the induction of electrical currents by magnets, and I have had built and used apparatus similar to that described by Faraday as used by him. I was present at the United States Centen-

In the Circuit Court of the United States,

FOR THE

EASTERN DISTRICT OF PENNSYLVANIA, IN THE THIRD CIRCUIT.

OF APRIL SESSION, 1884, No. 15.

AMERICAN BELL TELEPHONE COMPANY ET AL.

vs.

THE CLAY COMMERCIAL TELEPHONE COMPANY ET AL.

Testimony taken on behalf of defendant before Samuel Bell, Special Examiner, at the office of Furman Sheppard, Esq., No. 717 Walnut street, Philadelphia, this twenty-third day of March, A. D. 1885, and on subsequent days by adjournment.

Present: CHARLES HOWSON, *of Counsel for Complainants.*
FURMAN SHEPPARD, ESQ., *of Counsel for Respondents.*

Defendants' counsel offers in evidence the following publications, being those referred to by plaintiffs' witness Charles R. Cross, in his answer to cross-interrogatory 81, viz.:

Frankfurter Conversationsblatt, November 29, 1861.

Fortschritte der Physik xvii., for 1861, pp. 171–3.

Deutsche Industrie Zeitung, 1863. Chemnitz, April 17, 1863, No. 16, p. 184; May 1, 1863, No. 18, p. 208; May 29, 1863, No. 22, p. 249.

BÖTTGER'S Polytechnisches Notizblatt, 1863, No. 61.

REIS'S Letter to LADD, Journal of the Telegraph, Engineers, and of Electricians, for March, 1863, No. 46.

The Newcastle Daily Chronicle and Northern Counties Advertiser, Saturday, August 29, 1863.

Report of the Thirty-third Meeting of the British Association for the Advancement of Science, in August and September, 1863, published 1864.

Prospectus of MR. ALBERT, August, 1863.

Circular of REIS.

REIS's Descriptive Circular.

DINGLER's Polytechnic Journal, vol. clxix., p. 23.

Fortschritte der Physik, 1863, p. 96.

Gartenlaube REIS Improved Apparatus, No. 51, December, 1863.

COSMO's Description of REIS, vol. xxiv., pp. 349, 352. Printed and published at Paris, March 22, 1864.

CLIFTON's Description of REIS. Proceedings of the Literary and Philosophical Society of Manchester. Published at Manchester, 1865.

KOENIG's Description of REIS. "Catalogue des Appareils d'Acoustique," Paris, 1865, p. 5.

PISKO's Neuren Apparate der Akustik, Wien, 1865, p. 241.

Catalogue of J. W. ALBERT, Mechanician at Frankfort-on-the-Main, 1866.

Electricity, by R. M. FERGUSON, London, 1867, p. 257.

Lehrbuch der Physik und Meteorologie, von JOH. MULLER, Siebente Auflage, Zweiter Band, 1868, pp. 386–389.

The Manufacturer and Builder, May 1869, DR. VAN DER WEYDE'S article, The Telephone.

The Wonders of Electricity, translated from the French of J. BAILE, New York, Scribner, Armstrong & Co., 1872, pp. 140–143.

Catalogue of J. W. ALBERT, Mechanician at Frankfort-on-the-Main, 1873.

DR. VAN DER WEYDE'S second article, The Invention of the Telephone, Scientific American, March 4, 1876.

Report of the Exhibition of Scientific Apparatuses in South Kensington Museum, London, 1876, p. 188, Group 6, Sound 922.

Report of the Forty-seventh Meeting of the British Association for the Advancement of Science, held at Plymouth in August, 1871, article by W. H. PREECE *On the Telephone.*

The Telephone, by PROF. A. E. DOLBEAR, Boston, Lee & Shepard, 1877, pp. 99–116.

Also the following :—

Jahres Bericht des Physikalischen Vereins zu Frankfurt-am-Main. Für das Rechnungsjahr, 1860–1861, being Yearly Report of the Physical Society at Frankfort-A.-M., 1860-61, pp. 57-64. (Published in 1862.)

REIS Legat Article, being Journal of the German Austrian Telegraph Association, vol. 9, p. 1, 1862. Concerning the reproduction of sounds by means of galvanic electricity by V. LEGAT, Royal Prus-

sian Telegraph Inspector at Cassel, accompanied by copperplates VIII. and IX.

BOTTGER'S account of REIS' Improved Apparatus. DINGLER'S Polytechnic Journal, vol. 169, p. 399.

PISKO'S Description of REIS; PISKO die Neueren Apparate der Akustik, Vienna, 1865, pp. 94, *et seq.*

KUHN'S Description of REIS; Handbuch der Angewandten Elektricitätslehre Von KARL KUHN, 1865, pp. 1017–1021.

HASSLER'S Description of REIS; HASSLER'S Technical Physics, Vienna, 1866, vol. 1, 648.

It is agreed between counsel that counsel on either side may refer to the foregoing publications as contained in the pleadings, evidence, and exhibits in the case of the American Bell Telephone Company *vs.* A. D. Dolbear, in the United States Circuit Court, District of Massachusetts, and may reprint said publications as therein found.

Also a Lecture entitled "Researches in Electric Telephony," by Professor ALEXANDER GRAHAM BELL, delivered before the Society of Telegraph Engineers, October 31, 1877. Published by the Society and edited by Lieutenant-Colonel FRANK BOLTON, C. E., Honorable Secretary, and WILLIAM EDWARD LANGDON, Acting Secretary, and the same is marked "Defendant's Exhibit, Bell's Lecture."

Also specification provisional and Complete of English Letters Patent to WILLIAM MORGAN BROWN, of the firm of BRANDON and MORGAN BROWN, Engineers and Patent Agents, of 38 Southampton Buildings, London, and 1 Rue Laffitte, Paris, for an invention of "Improvements in Electric Telephony (transmitting or causing sounds for telegraph messages) and Telephonic Apparatus," communicated to him from abroad by ALEXANDER GRAHAM BELL, of the University of Boston, Massachusetts, United States of America, Professor of Vocal Physiology. Provisional specifications filed December 9, 1876, and completed specifications filed and sealed June 9, 1877; A. D. 1876, 9th of December, No. 4765, and the same is marked "Defendant's Exhibit, MORGAN BROWN'S Specification."

Also disclaimer and memorandum of alteration entered by the said WILLIAM MORGAN BROWN, of certain parts in the specification of the said Letters Patent pursuant to the statute in that case made and provided. Filed 13th February, 1878, and the same is marked Defendants Exhibit Memorandum of alteration of MORGAN BROWN.

Also, certified copy of file wrapper and contents in the matter of the Letters Patent granted to Alexander Graham Bell, March 7, 1876, No. 174,465, for improvement in telegraphy, and the same is marked

"Defendants' Exhibit, File Wrapper and Contents of No. 174,465."

Also certified copy of the file wrapper and contents in the matter of the Letters Patent granted to Alexander Graham Bell, January 30, 1877, No. 186,787, and the same is marked "Defendants' Exhibit, File Wrapper and Contents of No. 186,787."

Adjourned until Tuesday, March 24, 1885, at 12 o'clock M.

TUESDAY, March 24, 1885.

Met pursuant to adjournment.

Present: MR. SHEPPARD, *for Respondents;*
MR. DICKERSON, *for Complainants.*

Dr. Carl Seiler, being duly sworn on behalf of respondents, answering saith:—

Q 1. What is your name, age, residence, and occupation?

A. My name is Carl Seiler, physician, instructor in laryngology and lecturer on the diseases of the throat, and now at the University of Pennsylvania. I am thirty-six years of age. No. 1346 Spruce street.

Q 2. What attention, if any, have you paid to the subject of acoustics and electricity?

A. I have paid attention to the study of the laws of acoustics since early youth, both in its theoretical aspect and practical application. I may say, that at the time when Professor Helmholtz was preparing his work on the sensations of tone, he applied for help and verification of his experiments and calculations to my mother and myself, although I was then a child. Not trusting to the accuracy of his ear, he would almost daily come to my mother's house, explain to her his calculations, and have her verify them by actual test on the piano or other musical instruments. To make a further test by an unbiased mind, I, having a good ear, was called upon to point out on the piano or other musical instrument, such as the violin, what tone, if any, I heard. Since then my mind naturally dwelled upon investigations of this kind, and I have continued acoustic experimentation up to the present time.

I have paid considerable attention to electricity and its practical application in the healing art, as well as for scientific and practical purposes. I have had for several years a number of private telegraph

lines in my house, so that I was enabled to carry on communication electrically with a number of my friends for social as well as experimental purposes. I am also the originator of a battery used in this country more than any other for galvanic cautery.

Q 3. Please state what attention, if any, you have paid to the theory and practice of telephony.

A. I have ever since 1876, when I was fortunate enough to hear voice transmitted through the telephone, experimented with telephones and transmitters of various kinds and construction, mostly made by myself, and have used these different devices, as stated in Q 2, over private lines for social and experimental purposes.

Q 4. State whether or not you are acquainted from observation or experience with the construction and operation of the forms of telephonic devices which are in general use?

A. I am acquainted with most of the telephonic devices in general use, and many of those not in general use. I have experimented with these devices, and compared them with each other, so that I am acquainted with them both by experience and observation.

Q 5. State whether or not you have read the specification forming part of Letters Patent of Alexander Graham Bell for improvement in telegraphy, dated March 7, 1876, and No. 174,465, and also specification forming part of Letters Patent of said Bell for improvement in electric telegraphy, dated January 30, 1877, No. 186,787, and whether you think you understand the construction and operation of the devices therein represented and described?

A. I have read the two patents as obtained from the Patent Office, referred to in the question, the one dated March 7, 1876, and the other January 30, 1877, and I think that I understand and comprehend the working of the devices therein represented.

Q. 6. Are you acquainted with the investigations of Helmholtz, as contained in his work on the sensations of tone?

A. I am acquainted with the investigations as contained in his book on the sensations of tone, both by reading the original publication, and the translation of the same by Mr. Ellis, and may further state that I have made investigations in acoustics in Helmholtz' laboratory in Berlin, under his personal supervision and guidance, in the year 1871. I have tested for him, on that occasion, a new apparatus called a tone measure, constructed by Appun, which instrument Professor Helmholtz had just received, and in which the different tones were separated from each other by a difference of four vibrations per word, a difference which was appreciable to my ear in the lower octaves, but

not to his, and he therefore requested me to test the instrument by the ear alone, while he applied other tests.

Q 7. Please state the general nature of sound, and the method of its propagation.

A. Sound is a vibratory motion of the air. It is produced by an impulse upon the particles or molecules of the air, thus destroying for the time being their natural relation to each other as regards distance; so that the first effect of the impulse will be a compression or condensation of the air particles. The second effect will be a corresponding separation of these same particles of air, which separation, on account of the inherent elasticity of the particles, separates them further than when air is in the normal condition. This condensation and subsequent rarefaction or separation of the air particles is progressive in its nature, since the impulse which has been received by the first particle in the line is communicated to the next, and next, &c., with gradually diminishing force, so that by the time the rarefaction at the beginning of the line of air particles has been completed, the condensation has traveled some distance along the line. If the impulse is repeated at short intervals, the same phenomena will be repeated, and a whole row of condensations and rarefactions will take place along the line of air particles. This repetition of the impulses is termed vibration, or to and fro motion, and the condensation and rarefaction of the air particles is termed a wave. So that one vibration produces one wave of a certain length, and in many of the books on the subject the terms "wave-length," and "number of vibrations," are synonymous terms. This vibration of any body capable of performing such vibratory motion, and thus giving repeated impulses to the air particles, if it occurs at the rate of sixteen and a half motions or vibrations in a second, will produce air waves appreciated by the ear as a continuous sound. While on the other hand, if these vibrations exceed the number of forty thousand to forty-five thousand per second, they cease to be audible to the average ear. Any number of vibrations between these limits are appreciated by the ear as a continuous sound.

Sound is propagated through almost all known substances in *all directions* from the starting point, but with unequal velocity, corresponding to the density and elasticity of the medium through which the sound is propagated. Thus, for instance, sound travels at the rate of one thousand and ninety feet per second through air at the temperture of freezing point or zero Centigrade, and gains two feet in velocity for every degree of Centigrade that the temperature of the air is raised.

Numerous experiments have been made to determine the velocity of sound in different substances; and Tyndall, in his eight lectures on Sound, gives a table of figures representing the velocity of sound as transmitted through different substances. These condensations and rarefactions of the air, in other words, the sound-wave, being propagated along the line in any direction from the starting point, when striking the sensitive portions of the ear are perceived as sound, but they do not cease to be sound if the ear cannot appreciate them as such.

Q 8. Please describe and explain in what way it has been customary to represent graphically to the eye the propagation of sound?

A. It has been customary to represent graphically these condensations and rarefactions of the air by the sinusoidal curve or wave-line, such as is seen on the surface of the water when disturbed in its level by some external influence, such as the impulse of a stone thrown into the water. The stone then gives the first impulse and causes a receding of the water particles immediately affected by the shock until their elasticity will overcome the downward force of the stone, and they will rise in a perpendicular direction above the original level of the water; this motion of the water particles being communicated to the neighboring water particles, they all successively participate in this up and down motion, and the result is a wave-ring around the point in which the stone struck the water, which gradually widens until it either comes in contact with some solid obstruction or until the vibratory motion of the water particles has become reduced to nothing by the distance from the original source. Thus water-waves travel in all directions on the surface of the water, while air-waves are propagated absolutely in all directions; the water-waves are seen to consist of elevations and depressions of the surface of the water, and since their production is so similar to the production of air-waves, this wave-line or sinusoidal curve has been universally employed to graphically represent sound-waves.

Q 9. Is the sinusoidal curve a correct copy of what actually takes place in the propagation of sound? And in connection therewith please refer to Mayer on Sound, page 97, and state whether it does not contain the following lines: "The curve A C O R B is not a real picture of a sonorous wave; it is merely a good way of showing its length, and the manner in which the air is condensed and rarefied in it; for sonorous waves are not formed of heaps and hollows, like the waves you have seen on the sea. They are not heaps and hollows of

air, but only condensations and rarefactions of air. In short, Fig. 36 is merely a convenient symbol which stands for a sonorous wave."

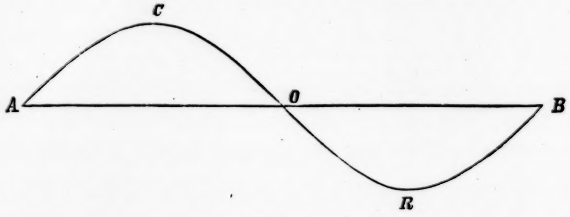


Fig. 36.

A. The sinusoidal curve used to graphically express the sound-wave, is not a correct representation of the condensation and rarefaction of the air particles composing a sound-wave. It is merely a convenient analogue which requires the explanation, when used to represent a sound-wave, that the elevation of the curve above the surface line corresponds to the rarefaction of the air particles, while the depression or furrow corresponds to the condensation of the air particles. I have examined the book referred to in the question, and find that it contains, on page 97, the lines quoted in the question.

Q 10. Please state what are the generally received elementary characteristics of sound.

A. The elementary characteristics of sound are three in number, namely, First: Pitch, or the position of the sound in the musical scale. In books on acoustics pitch of a sound is denoted by a letter representing the name of that sound, to which is added a number either above or below the letter denoting the position of the octave above or below the middle C of the piano. In music, pitch of a sound is represented by its position below, on, or about the ledger lines. Second: Intensity or loudness of sound, which is the degree of sensation received by the ear, or in other words it is the degree of violence by which the sensitive portions of the ear are actuated by the sound, but this intensity or degree of violence may also exert a mechanical influence upon bodies capable of vibration, other than the ear, and it depends upon the intensity of the sound how much mechanical force may result from it; as illustration I would quote the well-known phenomenon of the rattling of window panes when a sound of a certain intensity is produced in the room, which does not occur when the sound has not the required intensity, or in other words is not loud enough.

Third: Quality of sound is that peculiar characteristic by which

sounds of different instruments can be distinguished from each other when they are produced by different instruments with the same intensity, and are of the same pitch. For illustration I will quote from Helmholtz, English translation, page 27: "If the same note is sounded successively on a piano forte, a violin, clarionet, oboe, or trumpet, or by the human voice, notwithstanding its having the same force and the same pitch, the musical tone of each of those instruments is different, and by means of this tone we recognise with the greatest ease which of these instruments was used." Pitch corresponds to the length of the wave or number of vibrations in a given time, usually a second; intensity depends upon the width or amplitude of the wave or upon the size of the excursions of the vibrating body. Quality depends upon the shape of the wave or upon the manner in which the vibrations take place.

Q 11. What are the elements of the quality of sound?

A. The elements of the quality of sound are certain tones which sound together with the fundamental tone, thus producing a composite sound, the pitch of which is determined by the lowest or fundamental tone, while the others are termed overtones. This composite sound, which cannot be separated and divided into its component parts by the unaided ear, has been termed "klang" or "clang," which term was introduced into the English language by Tyndall, who obtained it from Helmholtz. The addition of these overtones to the fundamental tones thus produces this klang or clang, which, according to the number, order, and intensity of its component parts, will have a different quality if this intensity, order, or number of the component tones be changed. I will quote in illustration from Sedley Taylor's book on Sound and Music, published by MacMillan and Company, London, 1873, page 88 and following pages, the passage being as follows:—

"The phraseology hitherto employed, both in the science of acoustics and in the theory of music, goes on the supposition that the sounds of individual instruments are single tones, and therefore, of course, contain no terms specially denoting compound sounds, and their constituents. 'Sound,' 'note,' and 'tone,' are used as nearly synonymous. It will be convenient to restrict the meaning of the latter so that it shall denote a sound which does not admit of resolution into simple elements. A single sound of determined pitch, we shall, accordingly, in what follows, call a *tone* or *single tone*. In a compound sound the word *clang* will be a serviceable term. The series of elementary sounds into which a clang can be resolved, we shall call its *partial tones*, sometimes distinguishing among these the

lowest, or *fundamental tone*, from the others, or *overtones* of the clang. This nomenclature is a direct adaptation of the German terms employed by Helmholtz. Its introduction is due to Professor Tyndall, 47. This long discussion has paved the way for the complete explanation of musical *quality* which is contained in the following proposition: *The quality of a clang depends on the number, orders, and relative intensities of the partial tones into which it can be resolved.* We have here three different causes to which variations in the quality of composite sounds are assigned.

"1. A clang may contain only two or three, or it may contain half a dozen, or even as many as fifteen or twenty well-developed partial tones.

"2. The *number* of partial tones present remaining the same, the quality will vary according to the positions they occupy in the first series on p. 84, *i. e.*, in their *order*. Thus, a clang containing three tones may consist of (1), (2), (3), or of (1), (3), (5), or of (1), (7), (10), and so on, the *quality* varying in each instance.

"3. The *number* and *orders* of the partial tones present remaining the same, the quality will vary according to the relative degrees of loudness with which those tones speak. Thus in the simplest case of a clang consisting of (1) and (2), (2) may be twice as loud, or as loud, or half as loud as (1), and so on."

"It is clear that these three classes of variations are entirely independent of each other, that is to say any two clangs may differ in the number, orders, and relative intensities of their constituent partial tones. The variety of quality thus provided for is almost indefinitely great." The italics are in the original text.

Q 12. What is meant in acoustics by phase, and how, if at all, does it affect the quality of the sound or the form of the wave?

A. Phase in acoustics denotes the position of the wave as to the surface line, as well as in relation to another wave; for instance, if a wave commences at a given point, and another wave similar in diameter to the first wave commences a short period of time later, it is said to have a difference of phase from the first wave. According to Helmholtz, it is the addition of the waves of the overtones to that of the fundamental tone which produces the quality of the sound or the shape of the wave, and he states that phase has no influence upon the quality of the sound, although it may change the shape of the wave; he also states that differently-shaped waves may give the same quality of sound. Later investigations than those of Helmholtz, as to be found in the English translation, go to prove that the phase of the wave, or the differences of phases, produces an appreciable effect upon

the quality of the sound as well as upon the shape of the wave. An illustration of the difference of the shape of the wave as produced by the addition of a fundamental tone and its overtones, when differences of phase of the waves exist, is seen in a French work by Rudolph Koenig, of Paris, pages 227 and 228; the title of the book is as follows: "Quelques Expériences d'Acoustique par Rudolph Koenig. Paris, 1882." In the same book referred to, an account will be found of an experiment made by Dr. Koenig, which indicates that the difference of phase has an influence not only upon the shape of the wave, but also upon the quality of the sound. The instruments which were used in this experiment, and a diagram explanatory of the experiment, are found on pages 160 and 161, figures 43 and 44.

Q 13. What are the physical characteristics respectively of musical sound and noise; and what are the differences between them?

A. Musical sound as defined by physicists is periodic regular vibration, producing regular periodic air-waves; noise as defined is an irregular non-periodic vibration, producing irregular non-periodical air-waves. Musical sound, however, in spite of its periodicity, may become noise. When a number of musical tunes are sounded at once and without order the result will be noise, as for instance, if we depress a number of keys upon the piano irrespective of the musical relation of the individual tones sounded by the depression of the keys to each other, or more strikingly illustrated still, when a number of pieces of wood which have previously been tuned, each one to a definite pitch, are thrown together upon the floor, they will thus produce a noise, while if they are thrown upon the floor one after the other they will give rise to a series of tones closely resembling musical sounds. In the same manner when a repetition of the irregular wave periodic vibration producing a noise occurs at stated intervals, and when these intervals are less than the sixteenth part of a second, this noise may resolve itself into a musical sound, the pitch of which depends upon the number of repetitions of the noises in the given time, say a second. This may be illustrated by the experiment with the syren, in which a current of air is cut into a number of puffs by a rotating perforated plate; each one of these puffs in itself is a noise, but as soon as the disc is rotated with sufficient velocity so as to cut the current of air into more than sixteen and a half puffs per second, the resultant effect of the aggregation of these puffs is that of a continuous musical sound.

Adjourned till Wednesday, March 25th, 1885, at 11½ o'clock A. M.

WEDNESDAY, March 25, 1885.

Met pursuant to adjournment.

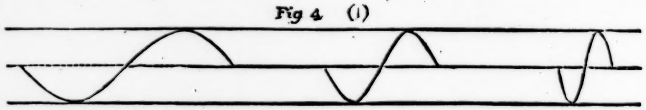
Present: MR. SHEPPARD, *for Respondents.*
MR. DICKERSON, *for Complainants.*

Dr. Carl Seiler, a witness for the respondents, resumes :—

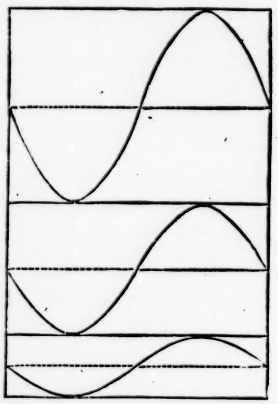
Q 14. Please refer to Taylor's work on Sound and Music, and state whether it does not contain, on page 13, the following words and drawing, viz. :—

"7. The *length, amplitude,* and *form* of a wave completely determine the wave, just as the length, breadth, and height of an oblong block of wood, *i. e.,* its three dimensions, fix the size of the block. These three elements of a wave are mutually independent, that is to say, we may alter any one of them without altering the other two. This will be seen by a glance at the accompanying figures.

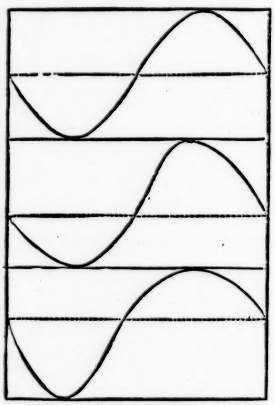
Fig 4 (1)



(2)



(3)



"(1) shows variation in *length* alone ; (2) in *amplitude* alone ; (3) in *form* alone."

A. I have referred to the page indicated in the book named, and have found that the passage referred to in the question is contained therein.

Q 15. Referring to the sinusoidal curve as a graphic expression of

the sound-wave, state how the three elementary characteristics of sound mentioned above by you are measured on said curve.

A. The three elementary characteristics of sound are measured on the curve in the following manner:—

First.—Pitch being the length of the wave, the length of the wave is measured by the distance separating the top of one crest from the top of the next crest, and applying this measurement to the air-wave as it actually exists, the length of the air-wave is measured by the distance separating the centre of a rarefaction from the centre of the next rarefaction.

Second.—Intensity being represented by the amplitude of the wave, the amplitude of the wave is measured by the vertical distance separating the top of the crest from the bottom of the furrow. If two lines are drawn parallel to the zero or surface line, touching respectively the top of the crest and the bottom of the furrow, the distance separating these two parallel lines will give the amplitude of the wave.

Third.—Quality of sound being represented by the shape of the wave, the shape of the wave cannot be measured, but it can be compared to a standard, which standard is the so-called normal or simple wave resulting from the vibratory motion of a pendulum, and is a wave the furrow and crest of which are composed of an arc of a circle. The composite wave, corresponding to the quality of a clang, is produced by the addition or fusion of a number of normal or simple waves, which differ more or less from each other in length and amplitude. The addition is made by erecting perpendiculars at regular intervals upon the zero or surface line in all of the waves to be added. Then by adding the lengths of these perpendiculars, measured from where they intersect the curve to the zero line, and then connecting the resultant lengths with each other, which will give a curved line differing in shape from either of the elementary waves which were added together. Any change in the amplitude of any of these waves will affect the resultant shape of the wave, since the perpendiculars are longer or shorter according to the amplitude of the wave. Further, a shifting to one side or the other of any of the elementary waves will also produce a change in the resultant shape, since then the perpendiculars are not added in equal sequence. This shifting of a wave is termed difference of phase.

Q 16. How is the shape of the sinusoidal curve altered by the addition of overtones to the fundamental note in producing the quality of the sound?

A. The shape of the wave is altered by the addition of overtones

to the fundamental tone, each one of which is represented by a normal or simple wave, by the addition of the waves to each other as explained in the foregoing question. The pitch of the resultant composite sound or clang is, however, not altered, but has the same number of vibrations as the fundamental tone. The intensity, however, is increased by the addition of overtones to the fundamental tone.

Q 17 What is meant by the persistence of vision, and state whether or not in the sense of hearing there is a persistence of audition analogous thereto?

A. By the persistence of vision is meant that well-known phenomenon observed in every eye, that an impression made upon the sensitive portion of the eye by light, direct or reflected, will keep up an impression of vision long after the light has ceased to actually make an impression upon the eye. In other words, the eye will believe to see a luminous body which has made an impression upon its sensitive portion even after the eye is screened from that impression; and it has been determined that the different colors of the spectrum, after having made an impression, are perceived by this residual sensation for different lengths of time.

In the ear an analogous persistence of sensation after the sound has ceased to exist has been demonstrated. Alfred Mayer, in the "American Journal of Science and Arts," October, 1877, has a paper in which he recounts a series of experiments made by himself with a view to determine experimentally the existence and duration of this residual sensation in the ear. By means of this experiment, which consisted in the rotation of a perforated disc between the prongs of a vibrating tuning fork and the mouth of its resonator, thus screening the resonator from the sound at regular intervals, and allowing the sound to pass through the perforations and through the resonator to the ear of the observer at corresponding intervals, he determined that such residual sensation exists in the ear; for he found that when the disc was rotated slowly the sound would be an interrupted one, but that as soon as the disc was rotated with a certain velocity the sound became continuous. Then by counting the number of revolutions of the disc in a given time and multiplying it by the number of intervals between the perforations, he arrived at the result given in the table of the paper referred to, and which in short words proves that the residual sensation of the ear is different in its duration for sounds of different pitch, ranging from one-sixteenth of a second for the C_1, to one one-hundred-and-thirty-fifth of a second for the C_5. I had occasion to verify these experiments at the time when they were made by Mayer in the

spring of 1874, and detected very slight errors in the results, which Professor Mayer removed.

Q 18. What is meant by the expression "vocal sound," and what is its organ?

A. Vocal sound is the utterance of a sound of voice, and it is common to all animals who possess the organ of voice. Each individual animal has a different quality of this vocal sound, and it can be recognized by the ear as belonging to the individual animal, provided the sound of the voice of the individual animal is familiar to the hearer.

The organ of voice, or vocal sound, is what anatomists call the larynx, and the particular portion of this organ connected with the production of sound are the vocal chords, which, being set in vibration by the current of air coming from the lungs, and being put in a state of tension by the muscles of the larynx, produce sound waves in the air. The pitch of this sound depends upon the amount of tension given to the vocal chords, and the intensity or loudness of the sound depends, in a measure, upon the force of the air current causing the vibration, but chiefly upon the addition of overtones added to the fundamental tone produced by the vocal chords in the resonant cavity of the mouth, throat, and nose, which also gives the distinctive quality of the voice.

Q 19. What is meant by articulate speech, and what is its organ?

A. Articulate speech is the series of sounds and noises uttered in arbitrary sequence to express ideas. These sounds and noises are divided into two classes, called vowels and consonants. The vowels are vocal sounds modified in the resonant cavities of the mouth, throat, and nose, in such a manner that pitch and intensity of the sound may be altered at will without destroying the characteristic peculiarity of each individual vowel. This individual peculiarity consists chiefly in the fact that during the pronunciation of the vowels the cavity of the mouth and throat is tuned to a definite pitch, which remains the same no matter of what age, sex, or nationality the individual may be, provided the same vowel is sounded. Donders and Helmholtz were the first to determine the exact number of vibrations of the pitch of the cavity of the mouth and throat during the pronunciation of the different vowels. Since then other observers have also determined these numbers of vibrations, and the difference of the results of the different observers lies chiefly in the position of the octave, a difference very difficult to verify or determine, especially in the upper portion of the scale. Helmholtz also states that for some of the vowels the cavity of the mouth gives two tones instead of one, because the rising

of the tongue against the palate divides the cavity of the mouth into two portions, each one of which is tuned to a different pitch. Other observers do, however, not agree with Helmholtz in this point, because the two cavities are connected with each other by a channel filled with air, thus making practically but one resonant cavity.

The consonants are noises produced by the more or less sudden interruption of the outflowing air current. This interruption is produced by the different portions contained in the cavities of the mouth and throat. This definition holds good for all consonants, except "m" and "n," which consonants consist in the gentle flow of breath through the nasal cavity, being obstructed at the opening of the mouth by the lips in "m," and the tip of the tongue in "n." Articulate speech may exist without vocal sound, and vocal sound may exist without articulate speech. The whispering voice is an instance of the first, and the song of the bird an instance of the second.

The organ, therefore, of articulate speech is a complex one, and consists of the cavity of the mouth, throat, and nose, and what is contained therein permanently.

Q 20. Does vocal sound include articulate speech according to the sense in which these respective terms are used by writers on this subject—and furnish illustrations if you are able to do so?

A. Vocal sound or voice is a different manifestation from articulate speech, for, as already indicated, the one may exist without the other. In fact, audible articulate speech is possible if the organ of voice, the larynx, has been removed, and a simple vibrating reed has been substituted for it, giving the individual what is termed an artificial larynx, and consequently an artificial voice. Even if no breath or air can pass from the lungs into the organs of articulation articulate speech is still possible, as is frequently observed by physicians in their practice. Writers on physiology and kindred subjects separate, in their treatment of the physiology of the voice, the two terms, "vocal sound" or "voice," or "song" and "articulate speech, articulation, or language."

In illustration of the foregoing, Draper, in his Human Physiology, 1875, p. 352, says: "For the further consideration of this subject it is necessary to understand that there is a distinction between song and speech. Song is produced by the glottis; speech by the mouth, or perhaps a more correct statement would be that the larynx is the organ of song, the mouth of that form of speech which we call whispering, and for which nothing is required but a stream of air issuing from the fauces, the tongue and other organs giving it articulation; but for

audible speech a noise is created in the larynx, and modified by articulation in the mouth."

Carpenter, in his Principles of Human Physiology, 1876, page 844, says:—

"It is necessary to bear in mind that vocal sounds and speech or articulate language are two things entirely different, and that the former may be produced in great perfection where there is no capability for the latter. Hence we might at once infer that the instrument for the production of vocal sounds is distinct from that by which these sounds are modified into articulate speech; and this we easily discover to be the case, the voice being unquestionably produced in the larynx, whilst the modifications of it by which language is formed are effected for the most part in the oral cavity."

Flint, in his text-book on Human Physiology, 1877, page 549 and following pages, treats the subject under the two heads of "voice" and "speech."

Marshall, in his Outlines of Physiology, London, 1867, vol. 1, page 248 and following pages, treats the subject in the same way. Lemuel Brown and Emile Behake, Voice, Song, and Speech, 1884, page 35, say: "Voice is sound originated in the larynx, and may be produced by any animal possessing that organ. Speaking is voice modified in the cavity of the mouth." This is the general mode of treatment by authors on the subject.

Q 21. Is the mode of the transmission of electrical action or electrical influence along a conductor known and understood?

A. The transmission of electrical action along or within a conductor is to my knowledge neither explained nor understood by physicists and electricians. Various theories have from time to time been propounded to explain this transmission of electrical action through a conductor, but none of them has been to my knowledge unanimously accepted as explaining this transmission.

Q 22. What is meant by the generally used expression "current of electricity"?

A. A current of electricity, so called, is not known to exist as a substance, and is only evidenced by the action produced upon certain instruments which are capable of being influenced by electricity. I therefore understand "current of electricity" to mean the transmission of electrical action, however directed, from the end of a conductor to a distant point of this conductor. The term "current" has been applied to this electrical action and its evidences, in the same manner as the sinusoidal curve has been employed to represent a

sound-wave; that is, as a convenient illustration easily grasped by the mind, and on which the different phenomena may be exemplified.

Q 23. What do you understand to be the meaning of the expressions "intermittent current," "pulsatory current," and "undulatory current"?

A. I understand the term "intermittent current" to mean that pauses occur in the evidences of electrical action at any point along a conductor. I understand by "pulsatory current" a certain and at intervals repeated increase or intensity of the evidence of electrical action; and I understand by "undulatory current" a gradual at intervals repeated augmentation of intensity of the evidence of electrical action along any point of a conductor.

Q 24. What is the difference, if any, between the graphic representation of the pulse, as given for instance by the sphygmograph, and the representation of a pulsatory current contained in the patent of Mr. Bell of 1876, in his lecture, and in his English patent?

A. The tracings of the pulse as given by the instrument called sphygmograph, which is in daily use by the medical profession for detecting abnormities in the arterial system, consist as a rule of a series of elevations and depressions produced by the up and down motion of the lever in contact with the pulse. The elevations are abrupt, that is to say the lever expends but a short time in reaching the highest point, while it gradually descends, and in doing so traces a more or less slanting line which may or may not have a smaller reproduction of the ascending line in it produced by a slight but sudden elevation of the lever occurring during the downward path. A simile would be the teeth of a saw in the more slanting portion of which one smaller saw-tooth was added. The figure in Mr. Bell's patent of 1876, the English patent, and in a reprint of his lecture, represents a figure which if produced by a lever in a similar manner as the sphygmograph produces the tracings of the pulse, the motion of this lever would be a sudden upward one, a remaining at rest for a certain length of time when the highest point has been reached, then a descending motion as sudden as the ascending one, and then again a period of rest when the lowest point was reached. We have, therefore, a representation which may be likened to a row of bricks set upon the floor at certain intervals, a very unlike figure from that presented by the teeth of a saw.

Q 25. State whether the terms "sudden" and "gradual," as applied to changes of intensity in a current, are capable of antecedent or precise definition; and whether or not a sudden change may not pass into a gradual change, and conversely a gradual change into a sudden change.

A. The terms "sudden" and "gradual" are, to my mind, not capable of being defined precisely, since they relate to time, or to the time during which a motion or change takes place. If, for instance, a motion reaches its maximum in a short space of time we call it a sudden motion, and if it reaches its maximum in a comparatively long time we call it gradual, so that in this respect "sudden" and "gradual" can no more be precisely defined than short and long. Applying this to changes in intensity of current, we must say that a sudden change is one which produces the greatest amount of evidence in a short space of time, while a gradual change of intensity in the current is one in which the greatest amount of evidence of electrical action is reached in a longer time. A change of intensity of the current may, therefore, be less sudden, and thus come nearer to a gradual change, until the two meet. A graphical representation of sudden and gradual changes of intensity respectively would be for the one the apex of a triangle, and for the other the arc of a circle, starting both from the same zero line, and having the same height. The height would then represent the greatest amount of intensity reached, while the line drawn from the starting point in the zero line of the ascending or descending line of the figures to the point of highest elevation, would double the time required to reach that greatest point of intensity.

Q 26. What is the nature of the undulatory current as it is described and represented in Mr. Bell's English patent of December 9, 1876, No. 4765?

[*Objected to by Mr. Dickerson as irrelevant and immaterial.*]

A. The current mentioned and diagrammatically represented in Mr. Bell's English patent is, in reality, a twofold one, for in the description on page 4, line 34 to 37, he says: "1st. The permanent magnet is caused to vibrate in front of the pole of an electro-magnet, which is placed in circuit with a voltaic battery, the undulatory current induced by the vibration of the permanent magnet is superposed upon the voltaic current." And in the diagram line 3, Fig. 6, sheet 1, he graphically represents these two currents the one as the third continuous line, and the other as a sinusoidal curve placed directly upon and without separation from the representation of the continuous current. In the same manner as if pieces of wood, cut out in sinusoidal curves, were glued upon a bar of wood, or, in other words, as though there was a trough of water with ripples in its surface, the body of the water representing the voltaic current and the ripples the induced undulatory current.

Q 27. Do you find in Mr. Bell's American patent of 1876, No.

174,465, a similar representation or description of the undulatory current?

A. I find that in the patent of Mr. Bell of 1876, the undulatory current is described not as an undulatory current superposed upon a continuous voltaic current, and find that in Fig. 4, sheet 1, the undulatory current is graphically represented as a sinusoidal curve having a zero or surface line.

Q 28. In what way, if at all, may it be determined if the current passing through a given line wire is an undulatory current or is a pulsatory current, and whether it is to be represented by the figure employed by Mr. Bell to represent a pulsatory current, or by that employed by him to represent an undulatory current?

A. I am not aware that an instrument exists which would act promptly enough to register or indicate sudden changes in intensity or gradual changes in intensity of a so-called current of electricity passing through a given line. Changes of intensity can readily be detected by instruments designed for the purpose, if these changes of intensity occur very slowly, that is, at long intervals; but even then the difference between sudden changes of intensity and gradual change of intensity must be very great to be detected. To illustrate. If two elements of a voltaic battery are connected with each other, and are immersed in the exciting fluid but a short distance, the heat developed in the conductor connecting the two elements may be measured; if now the elements are allowed to drop suddenly into the exciting fluid so as to be entirely immersed, a sudden increase of intensity and consequently heat is produced, which may be registered and measured with some degree of accuracy; and if on the other hand the elements of the battery are slowly lowered into the existing fluid a gradual increase of intensity and heat will follow, which also can be measured; but if these changes of intensity occur at all rapidly following each other, the registering or measuring instrument will not have time in the interval to return to its normal point, nor will, for instance, the conducting wire have an appreciable degree of heat during the interval of the up and down motion of the elements of the battery, so that the heat remains about the same in degree during the whole experiment. Therefore I do not think that it is possible to detect whether a pulsatory or undulatory current passes at a given time in a given wire or line. I therefore, also, do not think that a current passing at a given time over a given line can be represented by either the one or the other figure used by Mr. Bell to represent the pulsatory current and undulatory current respectively.

Q 29. Are you aware of any reason, either of a theoretical or practical character, which in your judgment requires that telephonic conversation should be effected only by a continuous undulatory current to the exclusion of a pulsatory or interrupted current?

A. After the answer given to me of the queries in this testimony in regard to the residual sensation of audition, there seems to me theoretically no reason why telephonic communication should not be possible or practicable, with an interruption recurring at frequent intervals either in the current or in the line. For in that answer the statements made by Mayer as to the existence and duration of the residual sensation of the ear and which I have experimentally been able to substantiate and satisfy my mind that such residual sensation exists; all that is necessary to carry on telephonic communication through an interrupted current or through a periodically interrupted line is that the periods of interruptions of the current and the period of breaks in the line shall be of less duration than the duration of the residual sensation of audition; but even for other reasons can I conceive the possibility of telephonic communication through an interrupted current or line provided the interruptions occur frequently enough, and are followed by a sufficiently long period of continuity of line or current so that the listener at the receiving end of the line may catch portions of the words; he will then connect and supply mentally the missing links without, perhaps, his being aware that he did not hear every sound that was sent at the transmitting station. A pulsatory current seems to me even less a hindrance to telephonic communication being carried on through or in spite of it, for the same reasons, and also for the reason that the difference between pulsatory current and undulatory current is not well defined.

Q 30. Is it necessary for the purposes of communication to hear every sound or word or syllable at the receiving station; and if not, why not?

A. I do not think that it is necessary to hear every word or sound during the conversation over a telephone line transmitted at the transmitting end because, as already stated, the mind will supply the missing links unconsciously if either the beginning or the end of a word or syllable is missing, provided the language in which the conversation is carried on is familiar to the person at the receiving end; if not, he will fail with the ear as well as in reading by the eye to quickly recognize the general characteristics of the word, and he then requires to hear every sound representing a letter or see every letter in the written

or printed word to recognize that word as having a definite meaning; practically the letters "m" and "n" are not received as sounds by the telephone, and are to be supplied by the context of the sentence and general character of the word. They are not sent, because they have no sound of their own.

Q 30′. Referring to Fig. 7 in Mr. Bell's American patent of 1876, No. 174,465, state whether or not, and how far if at all, the devices there represented differ from or correspond with those now generally employed in telephoning.

A. The device represented in Fig. 7, as I understand its mechanism from reading its description and examining the drawing, consists in the main of an electro-magnet at each end of the line actuated by a voltaic current supplied by a voltaic battery in close circuit, and a magnetic movable armature in connection with the membrane and vibrated before the pole of the electro-magnet at either end of the line by the vibration of the membrane when the latter is set in vibratory motion. The devices generally in use for practical purposes differ from the device just described, in the fact that no voltaic current or close circuit exists in the line wire; that further, a permanent magnet with a voltaic non-magnetic armature about which the wire of the line is wound in a coil is used as a receiver; and finally, that a transmitter actuated by the sound causes an induced current to be produced in the line wire at the time when conversation is carried on, or sounds are transmitted, and that the battery which is used is a local one, is an open circuit when not in use, and has no connection with the line wire except by induction, inasmuch as its circuit comprises within itself the transmitter and the primary coil of an induction coil. Therefore two batteries must be used to complete the sending and receiving apparatus at each end of the line.

Q 31. Are you aware that the device represented in Fig. 7 has ever been in use in practical telephony?

A. I am not aware that the device represented by Fig. 7 has ever been used in practical telephony, except perhaps for experimental purposes and purposes of demonstration in the lecture room.

Q 32. What instances, if any, occur to you of the use of a membrane in telephony or in acoustics prior to 1876?

A. The use of membrane or vibrating diaphragm was in telephony prior to 1876 by Reis, and also in the lovers or string telephone. I do not recall any other instances.

Q 33. What instances are there, if any, prior to 1877 of the use of a sounding box in connection with telephonic or acoustic apparatus?

A. The instances which occur to me are the Reis telephone, string telephone, Helmholtz' vowel apparatus, Koenig's manometric armature apparatus.

Q 34. What instances are there, if any, prior to 1877 of the employment of a hearing or speaking tube in connection with telephonic or acoustic apparatus?

A. A speaking tube was attached to the later devices of Reis' telephone, also in Koenig's manometric voice analyzer, a hearing tube in Koenig's new stethoscope and other stethoscopes, also in Scott's phonotograph; these are the instances which occur to me at the present time.

Q 35. Referring to the passage in the specification of the Bell patent of March 7, 1876, commencing with the words, "The advantages I claim to derive from the use of an undulatory current in place of a merely intermittent one," &c., state whether you understand the five advantages therein enumerated to refer to telegraphy or to telephony.

A. I have examined the passage referred to in the question, and it is my opinion that the passage refers solely to telegraphy, since the word signal is used in almost every claim. A spark arrester, a telegraphic appliance, is referred to, cable dispatches are mentioned, and the context of the passage would indicate that it would refer to telegraphy.

Q. 36. Referring to the testimony of plaintiff's witness, Charles R. Cross, in plaintiff's printed testimony, p. 117, as follows: "In Mr. Bell's patent, No. 174,465, a method is described by which the motions which are produced in the air at one place, the transmitting station, can be reproduced by an electrical method of intercommunication at the receiving station. By means of his invention he is able by the use of certain electrical apparatus to impress upon the particles of air at a distant place, the receiving station, motions substantially identical with those which are immediately impressed by the voice upon the particles of air at the transmitting station.

"According to the specification, he effects this result by the use of the transmitter, which takes up from the air at the transmitting station the motions which are impressed upon it by the voice of the speaker, and the vibrating portion of which transmitter moves in substantial accordance with the movements of the air particles themselves. This transmitter being connected with a line wire joining the two stations, between which speech is to be transmitted, is enabled, by its electrical connection with that wire, to produce in it electrical variations which correspond to and are similar in form to the motions

of the movable part of the transmitter, and hence to the motions of the air particles which have actuated the movable part of the transmitter. These electrical variations, in their turn, set in motion a movable part of a receiving instrument with which the line wire is connected, and, in their turn, produce in this movable part of the receiver vibrations corresponding to and similar in form to those electrical vibrations by which they are produced, and hence to the motions of the air particles at the transmitting station. The movable part of the receiving instrument, thus vibrating, impresses upon the air at the receiving station vibrations similar in form and corresponding to its own motions.

"The motions thus produced in the air particles at the receiving station are, therefore, evidently similar in form and correspondent to the original vibrations impressed upon the air at the transmitting station by the voice of the speaker at that station. This being the case, it is evident, from what I have said, that the sound uttered by the speaker at the transmitting station will be reproduced at the receiving station." Please state whether the general descriptive language there employed does or does not include the Reis devices, as they are described in the publications on that subject.

A. I have examined the passage referred to, and find from its context that it includes Reis' apparatus or device for electrically transmitting sound, as described in the publications containing a description of the device, and is included in the general character of the statement made in the passage.

Cross-examination by MR. DICKERSON.

× Q 37. When you said that the Fig. 7 of the patent "consists in the main of an electro-magnet at each end of the line actuated by a voltaic current," describe what you mean by the word "actuated" in that sentence.

A. I mean by the word "actuated" in the sense in which I used it in the quotation of the question, that the soft-iron core of the electro-magnet becomes a magnet only when a so-called current of electricity passes through the wire which surrounds it. This becoming of a magnet, thus changing the character of the iron core from non-magnetic to a magnetic, is the meaning of the word "actuated" as used in the passage.

× Q 38. The only function of the battery in that case is to keep the electro-magnet charged, which function would be equally well performed by the substitution of a permanent magnet? Is not that so?

A. I do not exactly understand as to the meaning of the word "charged," but supposed it to mean, keep the electro-magnetic in a state of magnetism, or in other words, to keep it magnetic, so that it is capable of attracting bodies or metals which can be attracted by magnets. The substitution of a permanent magnet for an electro-magnet does not include the wire of the coil around the core, nor does it include the line wire in which, in the device as depicted in Fig. 7, a continuous current passes.

× Q 39. If the cores were permanent magnets in Fig. 7, and the battery discarded entirely, the operation of the apparatus would be the same, would it not?

A. The operation of the device or apparatus would not be quite the same, since the force or intensity of a current which is developed by the vibrations of an armature in front of the pole of a permanent magnet which is induced in the wire wound around it depends upon the amplitude of the vibration of that armature, and since currents of opposite polarity are developed in the wire by this induction produced by the vibration of the armature, the device would, I think, work differently when there is no constant current passing in one direction along the line wire to oppose either the one or the other of the currents produced by the vibration of the armature.

× Q 40. Do you mean by that to say that there would be any difference in the effect on the electro-magnet at the remote end whether the electro-magnet were permanently magnetized or magnetized by the battery when the transmitter was spoken to?

A. I mean to say that if a current produced by a battery, or other device capable of supplying electricity, passes over the line wire in one direction it will oppose, in my opinion, a current of less intensity coming in the opposite direction over that same line wire, and it will therefore interfere more or less with the progress of this current of less intensity, so that the magnet at the receiving station must either be a permanent magnet, with the wire coiled around it when it is not what is called an electro-magnet, then no current of a voltaic battery will pass over the line, or else it must be an electro-magnet, that is an iron core surrounded by a coil of wire which becomes magnetic when a voltaic or other current of electricity passes through the coil, and it is then necessary that this current should pass over the line as in the device Fig. 7.

× Q 41. In either case is it not true that when the armature is set in vibration electrical undulations are created on the line wires?

A. I am not prepared to answer this question either in the affirma-

tive or in the negative, since I do not know what electrical undulations are. Electricity, as I understand it, is not a substance, but what it is I do not know, and I cannot conceive an undulation to take place in or be produced by anything but a substance.

× Q 42. You have just sworn that under certain circumstances an electric current was flowing and would be retarded by another current. Can you conceive of a current of that which is not a substance any more readily than you can conceive of undulations in that which is not a substance? And if so, explain to the court how that which is not substantial can flow in a current but can't undulate?

A. In the direct testimony, in answer to a question I have stated also under oath that the term current was a simple and easy symbol in order to explain and represent the evidences of electrical action, and that I did not conceive electricity to be a ponderable substance or fluid which, like water, runs in a current through a conductor. I can therefore also state that I cannot conceive electrical undulation, and would like to be understood that whenever the word current of electricity or electrical current is employed by me in this testimony it is a symbolic representation and not electricity itself.

× Q 43. And don't you also know that the term undulatory is commonly applied to the word current to express the variation in strength of current, similar to undulations in a pendulum or real bodies?

A. I have heard and made use of the expression "undulatory current," symbolically describing changes of intensity of strength of electrical current so called, but at the same time I have looked upon the expression merely as a makeshift to explain something I know nothing about—the method by which electrical action is transmitted through a conductor.

× Q 44. Doesn't the term convey a perfectly intelligible meaning to electricians notwithstanding their ignorance of the essence of electricity, and if you deny that, inform the court what term is used to express the action of an electric current whose strength varies in unison with the swing of a pendulum for illustration, if you think you are possessed of any better word than that commonly used?

A. I cannot answer as to the mental impression produced upon the brain of any of my fellow-men, and therefore cannot say what idea the term undulatory current raises in the minds of electricians. For my own part, the idea raised in my mind by the word or term undulatory current is a very vague and indefinite one, because of the endless variety of shapes and forms which undulations may assume. The illustration referred to in the question as to a current the variations of intensity of

which ought to be represented by the vibrations of the pendulum is only one of the innumerable undulations, and even that may differ and appear to the eye different under different circumstances. I would not like to suggest a new term or apply a new meaning to an old one, and for the reason that the nomenclature of electricity to my mind is already overburdened with names.

× Q 45. If you will neither accept the word in common use, nor do the world the favor to give it a better one, I find difficulty in asking a question without describing the phenomena each time, at whatever cost of time. And I now ask you whether it is not true in either of the cases referred to in respect to Fig. 7, that when the armature is known to vibrate to and fro, a current of electricity is set up on the line whose strength will increase and decrease in proportion to the movement of the armature, and thereby exhibit the phenomenon of what is called in the patent an undulatory current?

A. In the first place, I did not refuse to accept the word undulatory current or any other kind of a current as a purely descriptive term, nor did I deny that a current of electricity is produced in the line wire by the vibration of the armature in front of the magnet, whose changes of intensity correspond to the amplitude of the vibration of the armature, and the polarity of which current depends upon the direction of the vibration, so that no unnecessary time may be lost in making use of the word current of electricity, and to designate any other kind of a current; but I have no means of ascertaining beyond doubt whether an undulatory current or a pulsatory current, as the terms are defined in Mr. Bell's patent, passes over the line.

Adjourned till Thursday, March 26th, 1885, at 11 o'clock.

THURSDAY, March 26th, 1885.

Met pursuant to adjournment.

Present: Counsel as before.

Dr. Carl Seiler, a witness for the respondent, resumes:—

× Q 46. I call your attention to Professor Hughes' communication to the Royal Society of London, May 9, 1878, presented by Professor Huxby, and Professor Hughes' article on the same subject from the "London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science," volume VI., July, 1878, from which I quote some passages

tive or in the negative, since I do not know what electrical undulations are. Electricity, as I understand it, is not a substance, but what it is I do not know, and I cannot conceive an undulation to take place in or be produced by anything but a substance.

× Q 42. You have just sworn that under certain circumstances an electric current was flowing and would be retarded by another current. Can you conceive of a current of that which is not a substance any more readily than you can conceive of undulations in that which is not a substance? And if so, explain to the court how that which is not substantial can flow in a current but can't undulate?

A. In the direct testimony, in answer to a question I have stated also under oath that the term current was a simple and easy symbol in order to explain and represent the evidences of electrical action, and that I did not conceive electricity to be a ponderable substance or fluid which, like water, runs in a current through a conductor. I can therefore also state that I cannot conceive electrical undulation, and would like to be understood that whenever the word current of electricity or electrical current is employed by me in this testimony it is a symbolic representation and not electricity itself.

× Q 43. And don't you also know that the term undulatory is commonly applied to the word current to express the variation in strength of current, similar to undulations in a pendulum or real bodies?

A. I have heard and made use of the expression "undulatory current," symbolically describing changes of intensity of strength of electrical current so called, but at the same time I have looked upon the expression merely as a makeshift to explain something I know nothing about—the method by which electrical action is transmitted through a conductor.

× Q 44. Doesn't the term convey a perfectly intelligible meaning to electricians notwithstanding their ignorance of the essence of electricity, and if you deny that, inform the court what term is used to express the action of an electric current whose strength varies in unison with the swing of a pendulum for illustration, if you think you are possessed of any better word than that commonly used?

A. I cannot answer as to the mental impression produced upon the brain of any of my fellow-men, and therefore cannot say what idea the term undulatory current raises in the minds of electricians. For my own part, the idea raised in my mind by the word or term undulatory current is a very vague and indefinite one, because of the endless variety of shapes and forms which undulations may assume. The illustration referred to in the question as to a current the variations of intensity of

which ought to be represented by the vibrations of the pendulum is only one of the innumerable undulations, and even that may differ and appear to the eye different under different circumstances. I would not like to suggest a new term or apply a new meaning to an old one, and for the reason that the nomenclature of electricity to my mind is already overburdened with names.

× Q 45. If you will neither accept the word in common use, nor do the world the favor to give it a better one, I find difficulty in asking a question without describing the phenomena each time, at whatever cost of time. And I now ask you whether it is not true in either of the cases referred to in respect to Fig. 7, that when the armature is known to vibrate to and fro, a current of electricity is set up on the line whose strength will increase and decrease in proportion to the movement of the armature, and thereby exhibit the phenomenon of what is called in the patent an undulatory current?

A. In the first place, I did not refuse to accept the word undulatory current or any other kind of a current as a purely descriptive term, nor did I deny that a current of electricity is produced in the line wire by the vibration of the armature in front of the magnet, whose changes of intensity correspond to the amplitude of the vibration of the armature, and the polarity of which current depends upon the direction of the vibration, so that no unnecessary time may be lost in making use of the word current of electricity, and to designate any other kind of a current; but I have no means of ascertaining beyond doubt whether an undulatory current or a pulsatory current, as the terms are defined in Mr. Bell's patent, passes over the line.

Adjourned till Thursday, March 26th, 1885, at 11 o'clock.

THURSDAY, March 26th, 1885.

Met pursuant to adjournment.

Present: Counsel as before.

Dr. Carl Seiler, a witness for the respondent, resumes:—

× Q 46. I call your attention to Professor Hughes' communication to the Royal Society of London, May 9, 1878, presented by Professor Huxby, and Professor Hughes' article on the same subject from the "London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science," volume VI., July, 1878, from which I quote some passages

as follows: "The problem which the descriptions solves is this, to introduce into one electrical circuit an electrical resistance, which resistance shall vary in exact accord with sonorous vibrations so as to produce an undulatory current of electricity from a constant source, whose wave length, height, and form shall be an exact representation of the sonorous waves." And I ask you whether that statement does not convey to your mind an intelligible representation of the physical effect produced in the current of electricity by the means suggested?

A. The impression conveyed to my mind by the passage quoted in the question is that the effect of electricity at the other end of the line upon a device capable of receiving an impression is that of the reproduction of sonorous waves, but I cannot say that it conveys the idea of physically producing an effect upon the so-called current.

× Q 47. In that light, as you understand it, isn't there a clear distinction between a current represented graphically by Figs. 1, 2, and 3 of the Bell patent, and one represented graphically by Fig. 4?

A. I see by referring to the figures that there is a difference in the graphical representation of the so-called current, which to my mind simply conveys the idea of a different effect at the other end of the line.

× Q 48. Then so far as your mind apprehends the phenomena, these two forms of delineation do not convey to you any idea of a different condition on the line wire itself of the electrical current, but only a difference in the ultimate effect produced?

A. If I understand the question correctly, this is the idea conveyed to my mind.

(Counsel for complainant offers two articles marked respectively "Ex. Hughes, May 9th, 1878, Article," and "Ex. Hughes, June 8th, 1878, Article".)

× Q 49. In the Bell patent the following statement is made in respect to Fig. 7: "When a sound is uttered in the cone the membrane *a* is set in vibration, the armature *c* is forced to partake of the motion, and thus electrical undulations are created upon the circuit E *b e f g*. These undulations are similar in form to the air vibrations caused by the sound—that is, they are represented graphically by similar curves. The undulatory current passing through the electro-magnet *f* influences its armature *h* to copy the motion of the armature *c*. A similar sound to that uttered into A is thus heard to proceed from L." Does not that statement convey to your mind the idea that the electrical current, whatever it may be supposed to consist in, acts in its effect as

if it were a physical current undulating in unison with the undulations of air engaged in vibrating the diaphragm?

A. A reproduction of the vibrations of the armature, and membrane in connection with it, of the receiver in Fig. 7, if connected by a physical substance, such as the question asks us to imagine the current to consist in, as for instance a string, will be possible if the other end of the string be attached to the armature and through it to the membrane of the transmitter, but undulations such as graphically represented in the patent I do not think take place in that string.

× Q 50. Do you mean to say that the statement which I have quoted conveys no idea to your mind of the method whereby sound is transmitted in the telephone like Fig. 7?

A. I do not mean to say this, because I have, I think, a clear idea of the method of the vibration of the two armatures actuated or set in vibration by the other, through the medium of the so-called electrical current, but I mean to say that it does not convey an idea of what takes place in or upon the conducting wire.

× Q 51. Will you do the court the favor to express, in what you may suppose to be more intelligible terms than quoted from the specification, the method of operation whereby the vibrations of the diaphragm produced by the sound at the transmitting end are converted into similar vibrations in the diaphragm in the receiving end?

A. The vibrations of the armature in front of the magnet of the transmitter produce a variation of intensity in the source of electricity, and in consequence of these variations of intensity the magnetic force of the core of the electro-magnetic at the receiving station will fluctuate in harmony with these changes, thereby setting the armature and membrane in connection with it into vibrations. This is my idea of the process.

× Q 52. I observe that you leave out of your definition any reference whatever to the current of electricity as the intermediate link between the two ends. Do you think that with this omission your description of the action is as accurate as in the patent? And that the patentee made a mistake when he stated in substance that vibrations of the current might be represented graphically by similar curves to those which are used by scientists to represent the vibrations of the air particles engaged in causing the diaphragm to vibrate?

A. I have omitted a mention of the so-called electrical current because, as already stated, the term current is merely a symbol of something which we know nothing about; and I cannot give a definition or description of anything of which I know only the name. The con-

necting link between the two stations is the conducting wire, and I cannot answer the question whether the patentee has made a mistake or not.

× Q 53. Don't you know that the terms used in the patent, such as undulation and vibration, are those generally used by electricians to express the action of electricity in the so-called current, and that graphic curves are used by electricians to express variation of tension or strength of current, when electricity is exhibiting the phenomenon called the electric current?

A. I do know that the terms referred to in the question are used by electricians and even writers on electricity, but I do not know whether this usage of the terms referred to is general or not.

× Q 54. Have you ever before been called as an expert witness, to testify in respect to the science of electricity?

A. I have not.

× Q 55. So far as you do understand the subject, is it not evident to you that an apparatus operating in the manner described in the specification already quoted, must necessarily be capable of transmitting and reproducing the quality of any sounds uttered into the transmitter, whether those sounds are produced by the human voice or other means?

A. If mechanical details are such as to allow the free and unhindered vibration of the membrane at the receiver, theoretically the quality of sounds, producing a vibration of the membrane of the transmitter, will be reproduced in a measure more or less perfect according to the capability of the membrane at the transmitter to vibrate in such manner as to reproduce itself the quality of the sound. And in like manner the vibration of the membrane of the receiver must also be such as to reproduce itself the quality of any sound by which it is set in vibration.

× Q 56. You mean by all that to say, I suppose, that, theoretically considered, the apparatus should reproduce exactly the quality of the sound uttered into the transmitter, and to the extent that it fails to reproduce the quality of the sound exactly, and only reproduces a similar sound, that defect is due to the mechanical details which necessarily absorb a portion of the force, and, by their inertia and other qualities, to a certain extent reduce the effect which the theory calls for? Isn't that so?

A. Theoretically this is the meaning of my answer.

X Q 57. In your thirty-sixth answer, in which you interpreted a statement made by Professor Cross, you say "that it includes Reis'

apparatus or device for electrically transmitting sound, as described in the publications containing a description of the devices." Will you be good enough to refer the Court in any description of the Reis apparatus published before 1876 to any statement that the Reis instrument produced in the "receiver" vibrations corresponding to and similar in form to those electrical vibrations by which they are produced and hence to the motion of the air particles at the transmitting station?

A. I would state that in the answer to question thirty-sixth from which the sentence is quoted, the words, "in its general character," will be found to finish the sentence above quoted. When making that statement after having read the passage referred to, it seemed to me that the context conveyed the idea to the reader that the description in its general character applied to the descriptions of Reis' apparatus which I had seen. But I did not mean to say that any particular detailed description contained in the statement applied to the Reis apparatus.

I have seen statements in the literature that sounds of different quality had been transmitted by the Reis apparatus, and that the hearers at the receiving end were able to distinguish the sounds of different quality; but I cannot from memory give the title of the publication in which I saw statements of this kind, nor can I give the date of their publication.

× Q 58. Didn't you know or believe when you read that deposition of Professor Cross that he was discriminating between the method of the Bell patent and the method of the Reis instruments, and that in the context of the quotations which you have made he specifically pointed out the distinction between the two methods?

A. Having read only the quotation given in the question thirty-sixth, I did not know or believe that Professor Cross was discriminating between the two methods.

× Q 59. What did you mean in your answer when you said, "I have examined the passage referred to and find from its *context* that it includes Reis' apparatus or device?"

A. I am not sure, but I think that other words follow the quotation, from my answer, which make the answer clearer. At any rate, I meant that I had read over the passage, and that the idea conveyed to my mind by its general character was that what was said about Bell's device referred also to the description of Reis' apparatus. In other words, that the Reis apparatus was included in the general description given.

× Q 60. In what year did you first come to this country from Germany?

A. In the year 1868.

× Q 61. Helmholtz' book referred to by you was first published in 1862, was it not? And was the result, as he states in his preface, dated October, 1862, of eight years' labor?

A. As far as I know these statements are correct.

(Signed) CARL SEILER, M. D.

Sworn and subscribed before me this twenty-sixth day of March, A. D. 1885.

SAMUEL BELL,
Special Examiner.

× Q 60. In what year did you first come to this country from Germany?

A. In the year 1868.

× Q 61. Helmholtz's book referred to by you was first published in 1862, was it not? And was the result, as he states in his preface, dated October, 1862, of eight years' labor?

A. As far as I know these statements are correct.

(Signed) CARL SEILER, M. D.

Sworn and subscribed before me this twenty-sixth day of March, A. D. 1885.

SAMUEL BELL,
Special Examiner.

Carl Seiler, M. D., recalled, by counsel for defendants, and testifies as follows:—

Q 62. Please examine the Treatise on Human Physiology by John C. Dalton, Philadelphia, Henry C. Lea, 1875, and state whether, on pages 565 and 566, it does not contain the following:—

"In addition to its function in respiration, the larynx is also an "organ of vocal sound. * * * The actual formation of the "voice, or the production of sonorous vibration, takes place, there- "fore, exclusively in the larynx; while articulation, or the division of "the vocal sound into words and phrases by vowels and consonants, "is accomplished by the aid of the lips, tongue, teeth, and palate. "* * * Furthermore, as the two functions of vocalization and "articulation are accomplished by distinct nervous and muscular "actions, they may be deranged independently of each other, by injury "or disease of different parts of the nervous system. That of articu- "lation is regulated by the action of the facial and hypoglossal nerves, "while vocalization is under the control of the pneumogastric."

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"subscribers for express service only equipped with Bell magneto "telephones, without microphones. Each subscriber has one mag- "neto telephone which is used alternately as transmitter and re- "ceiver," and he offers to send for a competent witness to prove the truth of these statements. Counsel for respondents admits that such a witness could be produced and would so swear, and therefore waives the production of the witness.

Counsel for defendant offers in evidence the English Letters Patent of Cromwell Fleetwood Varley, of London, England, for Improvement in Telegraphing, No. 78,495, dated June 2d, 1868.

Also English Letters Patent of said Varley for Electric Telegraphs, No. 1044, dated April 8th, 1870.

Said patents are contained in the Dolbear Record, from page 631 to 639, and may be referred to by counsel and printed as therein.

Counsel for complainant offers in evidence the General Report of the Judges of Centennial Exhibition of Group XXV., pp. 20 and 21.

Also Report on Awards Centennial Exhibition, pp. 130 and 131. (Pp. 93 to 97, Dolbear Record.)

Also the newspaper publications in 1876 and 1877 in the same record, between pages 87 and 166.

[*Counsel for defendants object to the newspaper publications for irrelevancy and incompetency.*]

Carl Seiler, M. D., re-called, by counsel for defendants, and testifies as follows:—

Q 62. Please examine the Treatise on Human Physiology by John C. Dalton, Philadelphia, Henry C. Lea, 1875, and state whether, on pages 565 and 566, it does not contain the following:—

"In addition to its function in respiration, the larynx is also an "organ of vocal sound. * * * The actual formation of the "voice, or the production of sonorous vibrations, takes place, there- "fore, exclusively in the larynx; while articulation, or the division of "the vocal sound into words and phrases by vowels and consonants, "is accomplished by the aid of the lips, tongue, teeth, and palate. "* * * Furthermore, as the two functions of vocalization and "articulation are accomplished by distinct nervous and muscular "actions, they may be deranged independently of each other, by injury "or disease of different parts of the nervous system. That of articu- "lation is regulated by the action of the facial and hypoglossal nerves, "while vocalization is under the control of the pneumogastric."

A. I have looked at the work named, and it does contain the passage quoted.

Q 63. Please refer to the work entitled "The Telephone, the Micro-"phone, and the Phonograph," by Count Du Moncel, translated from the French, and republished in this country by Harper & Brothers, New York, 1879, and state whether, in referring, on page 72, to the effect of carbon and graphite in modifying the resistance of the circuit, he does not, in a note, use the following language:—

"This property has long been known, but not applied. In 1856, "in the second edition of my *Exposé des Applications d'Electricité*, I "pointed them out in speaking of the contact-breakers. I also "spoke of them in a paper on electro-magnets (published in the *Annales* "*Télégraphiques*, 1865), and in several articles laid before the *Académie* "*des Sciences* in 1872 and 1875, on the conductivity of filings and "conducting powers. M. Clérac, in 1865, also used them to obtain "variable resistances."

A. I have looked at the work named, and it does contain the passage quoted.

Q 64. Please refer to the same work by Du Moncel, viz., "The Tele-"phone, the Microphone, and the Phonograph," and state whether on pages 12, 13, 14, and 15, it does not contain the following passage:—

"From the telegraphic point of view, however, the problem of "transmitting sounds to a distance was far from being solved in this "way, and the idea of applying electricity to this mode of transmission "naturally arose as soon as the wonderful effects of electric telegraphy "were observed, that is, in the years subsequent to 1839. A surprising "discovery made in America by Mr. Page, in 1837, and afterward inves-"tigated by MM. Wertheim, De la Rive, and others, must also have led "up to it; for it was observed that a magnetic bar could emit sounds "when rapidly magnetized and demagnetized; and these sounds cor-"responded with the number of currents which produced them.

"Again, the electric vibrators devised by MM. Macauley, Wagner, "Neef, &c., and adapted to produce musical sounds, between 1847–1852, "by MM. Froment and Petrina, showed that the problem of transmit-"ting sounds to a distance was not insoluble. Yet, up to 1854, no one "had ventured to admit the possibility of transmitting speech by elec-"tricity; and when M. Charles Bourseul published, in that year, a paper "on the electric transmission of speech, the idea was regarded as a "fanciful dream. I confess that I myself thought it incredible; and "when I produced the paper in the first edition of my account of the "applications of electricity, published in 1854, I felt bound to add that "the scheme seemed more than doubtful. Yet, as the paper was "thoughtfully written, I had no hesitation in publishing it, affixing "the signature of Ch. B. Events justified this daring idea; and although "it did not include the only principle which could lead to the repro-

" duction of articulate sounds, yet it was the germ of the fertile inven-
" tion which has made the names of Graham Bell and Elisha Gray
" famous. For this reason I will again quote M. Charles Bourseul's
" paper.

" 'After the telegraphic marvels which can reproduce at a distance
" handwritings, or even more or less complicated drawings, it may
" appear impossible to penetrate farther into the region of the marvel-
" ous. Yet we will try to advance a few steps farther. I have, for
" example, asked myself whether speech itself may not be transmit-
" ted by electricity—in a word, if what is spoken in Vienna may not
" be heard in Paris. The thing is practicable in this way :—

" 'We know that sounds are made by vibrations, and are adapted to
" the ear by the same vibrations which are reproduced by the inter-
" vening medium. But the intensity of the vibrations diminishes
" very rapidly with the distance; so that it is, even with the aid of
" speaking-tubes and trumpets, impossible to exceed somewhat nar-
" row limits. Suppose that a man speaks near a movable disc, suffi-
" ciently flexible to lose none of the vibrations of the voice, that this
" disc alternately makes and breaks the currents from a battery; you
" may have at a distance another disc, which will simultaneously exe-
" cute the same vibrations.

" 'It is true that the intensity of the sounds produced will be variable
" at the point of departure, at which the disc vibrates by means of the
" voice, and constant at the point of arrival, where it vibrates by means
" of electricity; but it has been shown that this does not change the
" sounds. It is, moreover, evident that the sounds will be reproduced
" at the same pitch.

" 'The present state of acoustic science does not permit us to declare
" *a priori* if this will be precisely the case with syllables uttered by the
" human voice. The mode in which these syllables are produced has
" not yet been sufficiently investigated. It is true that we know that
" some are uttered by the teeth, others by the lips, and so on; but this
" is all.

" 'However this may be, observe that the syllables can only re-
" produce upon the sense of hearing the vibrations of the intervening
" medium; reproduce precisely these vibrations, and you will repro-
" duce precisely these syllables.

" 'It is, at all events, impossible, in the present condition of science,
" to prove the impossibility of transmitting sound by electricity.
" Everything tends to show, on the contrary, that there is such a pos-
" sibility. When the application of electro-magnetism to the trans-
" mission of messages was first discussed, a man of great scientific at-
" tainments treated the idea as utopian, and yet there is now direct
" communication between London and Vienna by means of a simple
" wire. Men declared it to be impossible, but so it is.

" 'It need not be said that numerous applications of the highest im-
" portance will immediately arise from the transmission of speech by
" electricity. Any one who is not deaf and dumb may use this mode
" of transmission, which would require no apparatus except an electric

"battery, two vibrating discs, and a wire. In many cases, as for ex-
"ample in large establishments, orders might be transmitted in this
"way, although transmission by electricity will not be used while it is
"necessary to go from letter to letter, and to make use of telegraphs
"which require use and apprenticeship. However this may be, it is
"certain that, in a more or less distant future, speech will be trans-
"mitted by electricity. *I have made some experiments in this direction ;*
"they are delicate, and demand time and patience, but *the approxima-*
"*tions obtained* promise a favorable result.' [The italics are in the original.]

"This description is certainly not full enough to enable us to discern
"from it the arrangement which would lead to the solution of the
"problem, and if the vibrations of the disc at the receiving-station were
"to follow from making and breaking the current at the sending-sta-
"tion, under the influence of vibrations caused by the voice, they
"would only produce musical, and not articulate sounds. Yet the
"idea was magnificent, as Mr. Preece said, even when he thought it
"impossible to realize it. Besides, it is easy to see that M. Bourseul
"himself was not deceived as to the difficulties of the problem, as far
"as articulate sounds are concerned, for he points out, as we have seen,
"the difference existing between the simple vibrations which produce
"musical sounds, and the complex vibrations which cause articulate
"sounds; but, as he justly said, 'Reproduce at the one end of the line
"'the vibrations of air caused at the other, and speech will be trans-
"'mitted, however complex the mechanism may be by which it is
"'effected.'"

A. It does contain the foregoing passage on said pages.

Q 65. Please refer to the same work by Du Moncel, viz., "The Tele-
"phone, the Microphone, and the Phonograph," and state whether on the pages from 126 to 136 it does not contain the following passage, viz. :—

"*Theory of the Telephone.*—It appears from the several experiments
"of which we have spoken that the explanation generally given of the
"effects produced in the telephone is very imperfect, and that the trans-
"mission of speech, instead of resulting from the repetition by the
"membrane of the receiving telephone (influenced by electro-mag-
"netism) of vibrations caused by the voice on the membrane of the
"transmitting membrane, is due to molecular vibrations produced
"in the whole electro-magnetic system, and especially on the magnetic
"core contained in the helix. These vibrations must be of the same
"nature as those which have been observed in resonant electro-mag-
"netic rods by MM. Page, De la Rive, Wertheim, Matteucci, &c., and
"these have been employed in telephones by Reis, by Cecil and
"Leonard Wray, and by Vanderweyde.

"According to this hypothesis, the principal office of the vibrating
"plate consists in its reaction, in order to produce the induced cur-
"rents when the voice has placed it in vibration, and by this reaction

"on the polar extremity of the bar magnet it strengthens the magnetic "effects caused in the centre of the bar when it vibrates under the "electro-magnetic influence, or at least when it is affected by the mag- "net. Since the range of these vibrations for a single note is great "in proportion to the flexibility of the note, and since, on the other "hand, the variations in the magnetic condition of the plate are rapid "in proportion to the smallness of its mass, the advantage of employ- "ing, as Mr. Edison has done, very thin and relatively small plates is "readily understood. In the case of transmission, the wider range "of vibration increases the intensity of the induced currents trans- "mitted. In the case of reception the variations in the magnetizing "force which produces the sounds are rendered clearer and more dis- "tinct, both in the armature membrane and in the bar magnet; some- "thing is gained, therefore, in each case. This hypothesis by no "means excludes the phonetic effects of the mechanical and physical "vibrations which may be produced in the armature plate under the "influence of magnetization and demagnetization to which it is sub- "jected, and these join their influence to that of the magnetic core.

"What is the nature of the vibrations sent into the receiving tele- "phone? This question is still obscure, and those who have studied it "are far from being in agreement: as early as 1846 it was the subject "of an interesting discussion between MM. Wertheim and De la Rive, "and the new discoveries render it still more complex. M. Wertheim "considers that these vibrations are at once longitudinal and trans- "verse, and arise from attractions exchanged between the spirals of "the magnetizing helix and the magnetic particles of the core. M. "De la Rive holds that in the case we are considering the vibrations "are simply longitudinal, and result from molecular contractions and "expansions produced by the different combinations assumed by the "magnetic molecules under the influence of magnetization and de- "magnetization. This appears to us to be the most natural explana- "tion, and it seems to be confirmed by the experiment made by M. "Guillemin in 1846. M. Guillemin ascertained that if a flexible iron "rod, surrounded by a magnetizing helix, is kept in position by a "vise at one end, and bent back by a weight at the other, it can be "made to return instantly to its normal position by sending a current "through the magnetizing helix. This recovery can in such a case "be due to nothing but the contraction caused by the magnetic mole- "cules, which, under the influence of their magnetization, tend to "produce intermolecular attractions, and to modify the elastic condi- "tions of the metal. It is known that when iron is thus magnetized "it becomes as hard as steel, and a file makes no impression on its "surface.

"It is, at any rate, impossible to dispute that sounds are produced "in the magnetic core, as well as in the armature, under the influence "of intermittent electric action. These sounds may be musical or "articulate; for as soon as the sender has produced the electric "action required, there is no reason why vibrations which are effected "in a transverse or longitudinal direction should transmit the one

"more than the other. These vibrations may, as we have seen, be "termed microscopic.

"Signor Luvini, who shares our opinion of the foregoing theory, "does not, however, think it wholly satisfactory, unless account is "taken of the reaction caused by the bar magnet on the helix which "surrounds it. 'There cannot,' he says, 'be *action* without *reaction*, "'and consequently the molecular action produced in the magnet "'ought to cause corresponding variations in the helix, and these two "'effects ought to contribute to the production of sound.' He sup- "ports this remark by a reference to Professor Rossetti's experiment, "of which we have spoken above.

"We believe, however, that this double reaction of which Signor "Luvini speaks is not indispensable, for we have seen that insulated "helices can produce sounds; it is true that the spirals, reacting on "each other, may be the cause of this.

"The difficulty of explaining the production of sounds in an "electro-magnetic organ destitute of armature caused the authenticity "of the experiments we have described to be at first denied, and "Colonel Navez started a controversy with us which is not likely to "be soon terminated; yet one result of this controversy is that Colo- "nel Navez was obliged to admit *that the sound of the human voice may "be reproduced by a telephonic receiver without a disc.* But he still be- "lieves that this reproduction is so faint that it is not possible to rec- "ognize articulate words, and he maintains that the transverse vibra- "tions of the disc, which are due to effects of attraction, are the only "ones to reproduce articulate speech with such intensity as to be of "any use.

"It is certain that the articulation of speech requires a somewhat "intense vibration which cannot easily be produced in a telephone "without a diaphragm; for it must be remembered that in an instru- "ment so arranged, the magnetic effects are reduced in a considerable "ratio, which is that of the magnetic force developed in the magnet, "multiplied by itself, and that so faint an action as that effected in a "telephone becomes almost null when, in consequence of the suppres- "sion of the armature, it is only represented by the square root of the "force which produced it. It is therefore possible that the sounds "which are hardly perceptible in a telephone without a diaphragm "become audible when the cause which provokes them is multiplied "by itself, and when there are in addition the vibrations produced in "the heart of the armature itself, influenced by the magnetizations "and demagnetizations to which it is subjected.

"In order to show that the action of the diaphragm is less indis- "pensable than Colonel Navez seems to imagine, and that its vibra- "tions are not due to electro-magnetic attractions, it will be enough to "refer to Mr. Hughes' experiments, which we have mentioned above. "It is certain that if this were the effect produced, we should hear "better when the two bar magnets present their poles of the same "nature before the diaphragm, than when they present the poles of "contrary natures, since the whole action would then converge in the

"same direction. Again, the more marked effects obtained with mul-
"tiple diaphragms in juxtaposition completely exclude this hypothe-
"sis. It is, however, possible that in electro-magnetic telephones the
"iron diaphragm, in virtue of the rapid variations of its magnetic
"condition, may contribute to render the sounds clearer and more dis-
"tinct; it may react in the way the tongue does; but we believe that
"the greater or less distinctness of the articulate sounds must be chiefly
"due to the range of vibrations. Thus Mr. Hughes has shown that
"the carbons of metallized wood employed in his microphonic speak-
"ers were to be preferred to retort carbons for the transmission of
"speech, for the very reason that they had less conductivity, so
"that the differences of resistance which result from differences of
"pressure are more marked, and consequently it is easier to seize
"the different degrees of vocal sounds which constitute articulate
"speech.

"It must be clearly understood that what we have just said only
"applies to the Bell telephone; that is, to a telephone in which the
"electric currents have such a faint intensity that it cannot be sup-
"posed there is any external attractive effect. When these currents
"are so energetic as to produce such an effect, a transverse electro-
"magnetic vibration certainly takes place, which is added to the mole-
"cular vibration, and helps to increase the sounds produced. But it is
"no less true that this transverse vibration by attraction or by move-
"ment of the diaphragm is not necessary for the reproduction of
"sounds, whether musical or articulate.

"We are not now concerned with the discussion of magnetic effects;
"there has been an advance in science since Colonel Navez started the
"controversy, and we must ask how his theory of the movements of
"the telephone diaphragm by attraction will explain the reproduction
"of speech by a receiving microphone destitute of any electro-mag-
"netic organ, and I can assert that my experiments show that there
"can be no mechanical transmission of vibrations, since no sound is
"heard when the circuit is broken or deprived of its battery. Colo-
"nel Navez must therefore accept the molecular vibrations. This cer-
"tainly gives us a new field for study; but it is because European men
"of science persist in remaining bound by incomplete theories that
"we have allowed the Americans, who despise them, to reap the glory
"of the great discoveries by which we have lately been astonished.

"The experiments quoted above show that sounds may be reproduced
"not only by simple helices without an electro-magnetic organ, but
"also by the plates of a condenser, in spite of the pressure exerted
"upon them; and when we add to this the effects I have just pointed
"out, it may be supposed that vibrations of sound must result from
"every reaction between two bodies which has the effect of producing
"abruptly and at close intervals modifications in the condition of their
"electric or magnetic equilibrium. It is known that the presence of
"ponderable matter is necessary for the production of electric effects,
"and it is possible that the molecular vibrations of which I have
"spoken may be the result of molecular movements, due to the varia-

"tions of the electric force which holds the molecules in a special "condition of reciprocal equilibrium.

"In conclusion, the theory of the telephone and microphone, con- "sidered as reproductive organs of speech, is still far from being per- "fectly clear, and it would be imprudent to be too positive on ques- "tions of such recent origin.

"The theory of the electric transmission of sounds in electro-mag- "netic telephones is somewhat complex. It has been seen that they "can be obtained from diaphragms of non-magnetic substance, "and even from simple mechanical vibrations produced by shocks. "Are we to ascribe them in the first case to the inductive reaction of "the magnet on the vibrating plate, and in the second case to the "movements of magnetic particles before the spirals of the helix? "The matter is still very obscure; yet it is conceivable that the mod- "ifications of the inducing action of the magnet on the vibrating dia- "phragm may involve variations in the magnetic intensity, just as we "can admit an effect of the same kind due to the approach and with- "drawal of the magnetic particles of the spirals of the helix; M. "Trève, however, believes that there is in the latter case a special "action, which he has already had occasion to study under other cir- "cumstances, and he sees in the current thus caused the effect of the "transformation of the mechanical labor produced amidst the mag- "netic molecules. The question is complicated by the fact that these "effects are often produced by purely mechanical transmissions.

"There is another point to consider, on which Colonel Navez has "made some interesting remarks; that is, whether the effects in the "receiver are stronger with permanent than with temporary magnets. "In the first model of the telephone, exhibited by Mr. Bell at Phila- "delphia, the receiver was, as I have said, made of a tubular electro- "magnet, furnished with a vibrating disc at its cylindrical pole; but "this arrangement was abandoned by Mr. Bell, with the object, as he "states in his paper, of rendering his instrument both a receiver and a "sender.* Yet Colonel Navez maintains that the magnet plays an "important part, and is even indispensable under the present conditions "of its form. 'It is possible,' he says, 'under certain circumstances, "'and by making the instrument in a special way, to make a Bell "'receiver speak without a permanent magnet, yet with an instrument "'of the usual construction the sound ceases when the magnet is with- "'drawn and replaced by a cylinder of soft iron. In order to restore "'the voice of the telephone, it is enough to approach the pole of a "'permanent magnet to the cylinder of soft iron. It follows from these "'experiments that a Bell telephone cannot act properly unless the disc "'is subjected to an initial magnetic tension obtained by means of a "'permanent magnet. It is easy to deduce this assertion from a con- "'sideration of the theory.'

"*These are his own words: 'The articulation produced from the instrument was "'remarkably clear, but its great defect consisted in the fact that it could not be "'used as a sending instrument, and thus two telephones were required at each "'station, one for transmitting and one for receiving spoken messages.'"

"The assertion may be true in the case of Bell telephones, which are "worked by extremely weak currents, but when these currents are re- "latively strong, all electro-magnets will reproduce speech perfectly, "and we have seen that M. Ader made a telephone with the ordinary "electro-magnet which acted perfectly.

"The action of the currents sent through the helix of a telephone "can be easily explained. Whatever may be the magnetic conditions "of the bar, the induced currents of different intensity which act upon "it produce modifications in its magnetic state, and hence the molecu- "lar vibrations follow from contraction and expansion. These vibra- "tions are likewise produced in the armature under the influence of "the magnetizations and demagnetizations which are produced by the "magnetic action of the core, and they contribute to the vibrations of "the core itself, while at the same time the modifications in the mag- "netic condition of the system are increased by the reaction of the "two magnetic parts upon each other.

"When the bar is made of soft iron, the induced currents act by "creating magnetizations of greater or less energy, followed by de- "magnetizations which are the more prompt since inverse currents "always succeed to those which have been active, and this causes the "alternations of magnetization and demagnetization to be more dis- "tinct and rapid. When the bar is magnetized, the action is differ- "ential, and may be exerted in either direction, according as the in- "duced currents corresponding to the vibrations which are effected "pass through the receiving coil in the same or opposite direction as "the magnetic current of the bar. If these currents are in the same "direction, the action is strengthening, and the modifications are effect- "ed as if a magnetization had taken place. If these currents are of "opposite direction, the inverse effect is produced; but, whatever the "effects may be, the molecular vibrations maintain the same reciprocal "relations and the same height in the scale of musical sounds. If the "question is considered from the mathematical point of view, we find "the presence of a constant, corresponding with the intensity of the "current, which does not exist in mechanical vibrations, and which "may possibly be the cause of the peculiar tone of speech reproduced "by the telephone, a tone which has been compared to the voice of "Punch. M. Dubois Raymond has published an interesting paper on "this theory, which appeared in *Les Mondes*, February 21, 1878, but "we do not reproduce it here, since his remarks are too scientific for "the readers for whom this work is intended. We will only add that "Mr. C. W. Cunningham asserts that the vibrations produced in a "telephone cannot be manifested under precisely the same conditions "as those which affect the tympanum of the ear, because the latter has "a peculiar funnel-shaped form, which excludes every fundamental "note, specially adapted to it, and this is not the case with the bars "and magnetic plates which possess fundamental notes capable of "greatly altering the half-tones of the voice. He considers the alter- "ation of the voice observed in the telephone must be ascribed to these "fundamental notes.

"*M. Wiesendanger's Thermophone.*—M. Wiesendanger, in an article "inserted in the *English Mechanic and World of Science*,' September "13, 1878, ascribes the reproduction of speech in certain telephones "to vibratory movements resulting from molecular expansions and "contractions produced by variations of temperature, and these vari-"ations would follow from the currents of varying intensity which are "transmitted through the telephonic circuits. He was conscious of "one objection to this theory, namely, that the movements of expan-"sion and contraction due to heat are slowly produced, and conse-"quently are not capable of substantial action, rapid enough to pro-"duce vibrations; but he considers that molecular effects need not "take place under the same conditions as those which are displayed in "the case of material substances.

"M. Wiesendanger believes that this hypothesis will explain the re-"production of speech in the receiving microphones of Mr. Hughes, "and that it may even be applied to the theory of the electro-magnetic "telephone, if we consider that a magnetizing helix, as well as a mag-"netic core, round which an electric current circulates, is more or less "heated, according to the intensity of the current which traverses it, "especially when the wire of the helix and the core are bad conductors "of electricity and of magnetism. Pursuing this idea, M. Wiesendan-"ger has sought to construct telephones in which calorific effects are "more fully developed, and with this object he used very fine wire of "German silver and platinum to make the coils. He ascertained that "these coils could produce sounds themselves, and, to increase their "intensity, he put them between discs of iron, or on tin tubes, placed "on resonant surfaces close to the discs. In this way he says that he "was able to make a good receiving telephone without employing mag-"nets. He afterward arranged the instrument in different ways, of "which the following two are the most noteworthy:—

"In the first, the electro-magnetic system was simply formed by a "magnetic disc with a helix wound round it, of which the wire was in "connection with the circuit of a microphone, and which was fastened "to the centre of the parchment membrane of an ordinary string tele-"phone; the disc consisted of two iron plates separated by a carbon "disc of smaller diameter, and the whole was so compressed as to "form a solid mass.

"In the second, the helix was wound on a tin tube, six inches long "and five-eighths of an inch in diameter, which was soldered by merely "a point to the centre of the diaphragm of an ordinary telephone.

"The inventor asserts that the tube and diaphragm only act as re-"sonators, and that the sounds produced by this instrument are nearly "the same as those obtained from the ordinary string telephone; the "tunes of a musical box were heard, and the reproduction of speech "was perfect, both in intensity and in distinctness of sound; it even "appeared that telephonic sounds were audible with the tin tube alone, "surrounded by the helix. M. Wiesendanger says that 'these dif-"'ferent receiving telephones show clearly that the diaphragm and "'magnet are not essential, but mere accessory, parts of a telephone.'"

A. I have examined the book, and find that it contains the passage quoted.

Q 66. Please examine the book entitled "Electricity: its Theory, "Sources, and Applications. By John T. Sprague, Member of the "Society of Telegraph Engineers and Electricians. Second edition "(greatly enlarged). London: E. & F. N. Spon, 16 Charing Cross. "New York: 35 Murray street. 1884;" and state whether on pages 594 and 595 it does not contain the following passage:—

"*The Telephone.*—This instrument has come into practical use "almost from the day of its first real introduction, and, unlike most "inventions, was perfected at once. But this only applies to the ac- "tual instrument—to Bell's telephone, which, notwithstanding numer- "ous claimants to improvement, remains the best for general use. It "is not intended here to enter into an examination of the various "claims to the origination of the telephone beyond the remark that "it is pretty clear that Reis fully conceived the idea, and made a "working apparatus, which, if not perfect, only required a little use to "make it so; but his idea remained fruitless, though it may probably "have been the germ from which the later successful instrument was "derived. There are many people who, doing little themselves for "the world, appear to find a pleasure in fancying they diminish the "credit of a successful worker by pointing out that some one had "anticipated him, and the vaguest intimation of the possibility of "something being done, is quite enough for these people. On the "other hand, an idea once published and become, as it were, public "property, becomes a seed which germinates in another mind, and "that mind perfects it, possibly without an idea as to whence the fer- "tile suggestion was derived, and without this origin in the least "diminishing the merit of the person who has ultimately brought the "idea to completion.

"It is right to recognize that Reis really brought the telephone near "perfection, and Professor Syl. Thompson has done good work in "demonstrating the fact; nor is it unlikely that the work of Reis "directly or indirectly influenced the mind of many people, and among "them that of Bell while working out the subject. But we must "recognize that Bell *did work it out*, and is its legitimate inventor. "Equally certain is it that the completion of the practical system of "telephony is due to Professor Hughes, whose microphone, *freely* "*given to the world*, is the basis of the numerous patents and so-called "inventions for the transmitting part of the system." [The italics are in the original.]

A. I see that the book contains the passage quoted.

Q 67. Please examine the book entitled "Traité élémentaire de Physique par A. Ganot. Dix-neuvième édition, entièrement refondue, comprenant les matières indiquées par les programmes de 1880, pour l'en-

seignement scientifique dans les lycées, pour l'examen du Baccalauréat ès sciences, pour l'admission à l'École de Saint-Cyr et à l'École centrale ainsi que les compléments nécessaires pour les cours de l'École polytechnique (nouveau programme) et de l'École normale supérieure. Par Georges Maneuvrier, ancien élève de l'École normale supérieure agrégé des sciences physiques et naturelles, répétiteur à l'École des hautes études (Sorbonne). Ouvrage contenant 1014 gravures intercalées dans le texte et deux planches en couleur. Paris, librairie Hachette & Cie., Boulevard St. Germain, 79, 1884;" and state whether it does not contain, on page 1072 and 1073, the following passage:—

"Cette théorie du téléphone à plaque de fer doux n'est pas com-
"plète. Les vibrations de la plaque vibrante ne paraissent pas dues
"uniquement aux variations de magnétisme de l'aimant. La mesure
"de l'intensité des courants induits dans le téléphone Bell a prouvé
"qu'ils sont beaucoup trop faibles pour produire les vibrations de la
"plaque simplement par attractions et répulsions magnétiques. De
"plus, si l'on substitue à la plaque de fer doux des plaques nonmag-
"nétiques, de verre, de cuivre, de bois, &c., les sons sont encore trans-
"mis, quoique avec une intensité beaucoup moindre. Sans rejeter les
"courants induits développés dans le fil des bobines par l'induction de
"la plaque de fer doux du transmetteur, on est donc conduit à ad-
"mettre en outre que l'étui du téléphone et le barreau aimanté entrent
"eux-mêmes en vibration sous l'influence de la voix, et que ce sont
"leurs vibrations moléculaires qui se transmettent par les fils de cuivre
"jusqu'à la caisse du récepteur.

"En résumé, les actions et réactions dont ce téléphone est le siége
"ne sont pas aussi simples qu'on l'avait cru tout d'abord, et l'on peut
"dire que *la théorie de cet instrument est encore à faire.*" [The italics are in the original.]

A. The book does contain the passage quoted.

Q 68. Please state whether the above passage is not correctly translated as follows:—

"This theory of a telephone with a disc of soft iron is not complete.
"The vibrations of the vibrating disc do not appear to be due solely
"to the magnetic variations of the magnet. The measure of the inten-
"sity of the induced currents in the Bell telephone has proved that
"they are a great deal too feeble to produce vibrations of the disc
"simply by magnetic attractions and repulsions. Moreover, if non-
"magnetic discs of glass, copper, wood, &c. are substituted for a disc
"of soft iron, the sounds will be transmitted still, though with much
"less intensity. Without rejecting the induced currents which are de-
"veloped in the wire of the bobbins by the induction of the disc of
"soft iron of the transmitter, one is therefore led to admit, besides,
"that the box of the telephone and the magnetic bar themselves enter
"into vibrations under the influence of the voice, and that their molec-

"ular vibrations are transmitted by the copper wires to the case of the "receiver.

"Upon the whole, the actions and reactions of which the telephone "is the seat, are not so simple as was at first thought, and it may be "said *that the theory of this instrument is yet to be made.*" [The italics are in the original.]

A. I consider the foregoing translation to be correct.

Q 69. Please examine the book now shown you, entitled "Electricity "and Magnetism. By Fleming Jenkin, F. R. S. S. L. & E., M. I. C. E., "Professor of Engineering in the University of Edinburgh. Sixth edi-"tion. London: Longmans, Green & Co., 1881;" and state whether or not it does not contain on pages 376 and 377 the following passage:—

"The explanation of the action of the instrument (the Bell tele-"phone) given above agrees with that given by its inventor. Some "curious facts, however, led many to believe that this explanation is "not the true one. It has been discovered that instead of the thin ferro-"type disc of iron a thick plate might be used, and it has been assert-"ed that this plate could not possibly bend enough under the influence "of the voice to induce currents by its deflections. The word *bend* "may be quite inapplicable to such a case, but the surface opposite "the magnet does certainly advance and recede, or it would not trans-"mit sound to the air in contact with it. This alternate advance and "recess would take place if, instead of a ⅜ plate, we had a rod many "feet or many yards long. A far more singular fact has been dis-"covered by many observers, namely, that non-magnetic and even "non-conducting substances might be used instead of a ferrotype disc "in the receiving instrument, and lastly that the receiving instrument "will work, though very feebly, with no disc whatever. In this case "it seems clear that the Page effect, as it may be called, *i. e.* the noise "made by the magnet itself as its particles rearrange themselves with "each change of stress, is the source of the sound heard. This sound "becomes articulate as soon as its increase and decrease follow the "increase and decrease produced by the voice at the sending end. It "is obvious that when the currents sent are those due to the Bell disc, "the sounds from the Page effect must approximately at least corres-"pond with those which the ferrotype receiving disc would give off. "Thus when the ferrotype receiving disc is present we hear at least "two simultaneous voices; the voice of the disc which is strong, and "the voice of the magnet which is weak. When for the ferrotype "disc we substitute a wooden plate, this plate will act as a sounding-"board for the Page effect. When the plate is a conductor currents "will be induced in it by the change in the magnetic field, and these "will tend to move the plate in such a way as to give a third source "of sound which might be called the Ampère effect. A fourth source "may be due to the sound produced in the wire itself as the current "changes in intensity. This sound was first observed by M. De la Rive,

"and his observations have been lately confirmed by Dr. Ferguson in "Edinburgh."

A. I have examined the book, and find that it contains the foregoing passage.

Q 70. Please examine the book now shown you, the title of which is as follows: "The Modern Application of Electricity, by E. Hospitalier, "translated and enlarged by Julius Maier, Ph. D., Science Master, Chel- "tenham College; second edition, revised, with many additions; in two "volumes;" volume one relating to Electric Generators, and Electric Light; volume two relating to Telephone; various applications; Transmission of Energy; having the imprint of Kegan Paul, French & Co. No. 1 Paternoster Square, London, 1883; and state whether it does not contain on pages 5 and 6 of the second volume the following passage:—

"It cannot be doubted that Reis' instrument can reproduce articu- "late speech; it may not have done so before the invention of the Bell "telephone, although there is evidence that the Reis instrument did "reproduce articulate speech in 1862; but it cannot be denied that "Reis was the first inventor of an instrument for producing undu- "latory currents in a closed circuit; that he was the first to use undu- "latory currents to reproduce sounds with the assistance of the gal- "vanic battery, and that he was the first to invent an instrument which "reproduced articulate speech. As in the case of Pacinotti's machine, "so also here, it is one thing to make a great discovery, and quite "another thing to utilize it and make it commercially successful. "Reis, the poor artisan, without having himself realized the greatness "of his invention, died poor as he had lived, in 1874; and a few years "after, Professor Bell had the good fortune to announce to the world "his speaking telephone, in which the principles of the Reis receiver "are found in an instrument in which the bar armature of the Reis is "changed into a circular armature."

A. I have examined the book, and find that it does contain the passage quoted.

Q 71. Please examine the same work and say whether or not it contains, on pages 43 and 44 of the same volume (the second), the following passages:—

"*Battery Telephones.*—In magnetic telephones the transmitter acts "like a real generator of electricity; the mechanical work of the voice "is partly transformed into induction currents, and these currents, on "passing into the receiver, make it vibrate synchronically with the "membrane of the transmitter. The currents sent along the line must, "therefore, have a limited intensity, and in no case will the receiver "be able to emit more powerful sounds than those emitted before the "transmitter.

"The case is different with battery telephones. In these apparatus, "the vibrations of the transmitter are no longer utilized to produce "currents, but conveniently to distribute those emanating from a con- "stant source; their intensity is, therefore, only limited by that of the "source employed. Under these conditions the power of the receiver "can be very great, and even repeat with more intensity the sounds "emitted before the transmitter. The microphone will offer a number "of these examples.

"All transmitters of battery telephones are founded on the same "principle—to utilize the vibrations of a plate, or some such piece, "in order to produce a variation of the electrical resistance of a cir- "cuit, and consequently to modify to a certain extent the intensity of "the electric current traversing that circuit.

"This general principle requires the transmitter to be composed of "a special substance, with variable resistance, more or less ingeniously "arranged in the circuit, and modifying its resistance under the influ- "ence of the vibrations it receives. From this results a very simple "classification of the battery transmitters, depending on the nature "of the substance which is instrumental in producing the variable "resistance.

"We distinguish three classes of battery transmitters:—

"1. Liquid transmitters, in which a liquid is employed to produce "variable resistance.

"2. Transmitters with voltaic arc, in which a thin layer of air and "high tension currents fulfill this function.

"3. Carbon transmitters, the only important and practical ones, "comprising microphones.

"We shall only say a few words on the two first classes, which have "not given satisfactory results in practice, reserving a larger space for "carbon transmitters, which are now exclusively used."

A. The book does contain the above passages.

Q 72. Please examine the same work and say whether or not it contains on pages 119, 120, 121, and 122 of the same volume (the second) the following passage:—

"*Theory of the Telephone.*—The theory of the transmitter pre- "sents no difficulty, and has been explained several times in the pre- "ceding pages; we need not refer to it again. The discussions which "arose on the theory of the telephone especially referred to the receiv- "ing apparatus. How does a receiver—Bell's telephone, for instance—. "transform an undulatory current into an articulate sound? What are "the physical phenomena which bring about this transformation?

"We have admitted as a provisional theory, convenient for the "explanation of the apparatus, that the undulatory current produced "in the receiver a successive strengthening and weakening of the "magnetic force of the magnet, which manifested itself by greater or "lesser attractions of the plate, which then vibrated synchronically

"with the undulations of the current and the magnetic power of the "magnetized bar.

"This plausible explanation is sometimes verified in battery tele- "phones with carbon transmitters, but it is inadmissible with Bell's "telephone. Count Du Moncel, who from the outset rejected this "explanation, has seen his ideas partly confirmed by the numerous "experiments which have followed Bell's invention; now-a-days his "theory is almost universally adopted, and we are going to put it "before our readers in a few words.

"Numerous experiments and measurements made by Warren de la "Rue, Brough, Galileo Ferrari, and others, have proved that the "intensity of the currents developed by Bell's telephone does not "exceed that of Daniel's element after having traversed 10,000,000 "kilometres of telegraph wire—that is to say, 100,000,000 ohms— "which represents a telegraphic circuit of a length equal to 250 "times the circumference of the earth.

"This makes it very difficult to believe that the difference of mag- "netism produced in the magnetized bar by currents of such feeble "intensity could manifest themselves by variations in the attraction of "the vibrating plate placed at a distance.

"Bréguet's experiments, made with plates of fifteen centimeters "thickness, and Ader's, who employed no plate at all, put an explana- "tion based on magnetic attractions alone out of the question.

"Page's experiments have shown that an iron rod placed in a bob- "bin vibrates under the influence of interrupted currents. Reis' "musical telephone is, as we have seen, a practical application of this "phenomenon. These vibrations are occasioned in the very core "itself by successive changes of magnetization of the core. In Bell's "telephone the core vibrates longitudinally under the influence of the "undulatory current traversing the bobbin.

"This second phenomenon, however, is not sufficient to explain "Ader's telephone without magnetic core; a third influence must be "admitted, due to the action of the spirals of the helix upon each "other. In other cases the helix and the magnetized bar act upon "one another, and this contributes to the production of sounds.

"Sometimes a fifth influence of purely mechanical origin is at "work, manifesting itself in the same way as the transmission of "sound through solid bodies. Crépaux's experiments (page 104) "are the most curious and most remarkable instance of this.

"In a given telephone, the five agencies which have been mentioned "are not all at work with the same energy; sometimes one of them "is predominant, others disappear completely. In certain cases all "five act, but not with the same degree of energy. In certain tele- "phones the vibration of the plate itself plays a rather important part "in giving to the transmitted sounds a very peculiar timbre, but this "is chiefly the fault of the transmitter, which sends a deformed undu- "latory current along the line by the very action of its vibrating "plate.

"And yet it would be a mistake to conclude from all this that tele-

"phonic currents coming from a magnetic transmitter cannot produce "vibrations in a diaphragm by purely magnetic attraction. Ader's "alarum, for instance, acts with currents developed by Gower's mag- "netic telephone. Here we have a direct magnetic action producing a "veritable attraction.

"These various considerations will sufficiently show that the theory "of the telephone is very complicated, and that it is very difficult "exactly to define the part played by each of the agencies at work. "The numerous discussions on this subject arise from the fact that "the influence of each of these agencies has been exaggerated indi- "vidually, and at the expense of the others. The truth is that they "are simultaneous, and manifest themselves with a different degree "of intensity for each particular case. In any case, it is quite certain "that molecular action, which is as yet so imperfectly known, plays "an important part in acoustic phenomena, and that the telephone, "like the phonograph, will give a new impetus to research in this "direction, by opening up for that branch of physical science a new "horizon as vast as it is unknown."

A. That passage is to be found in the book at the place mentioned in the question.

Q 73. Please examine the book entitled "A Text Book of the Principles of Physics, by Alfred Daniell, M. A., Lecturer on Physics in the School of Medicine, Edinburgh. London: Macmillan & Co., 1844;" and state whether it does not contain, on page 423, the following statement:—

"When a compound sound is produced the basilar membrane is "set in motion in a number of limited regions at the same time, and "the effect is mingled in the brain. The nature of the compound sen- "sation by which we thus recognize the different qualities of sound, is "a question which passes the bounds of physics.

"The ear has a certain power of persisting in vibrations once set up "in it; but only in a small degree, and to an extent the greater the "lower the pitch of the note. If the sound C^1 be broken up by alter- "nate flashes of sound and silences of equal duration, when these "each number one hundred and thirty per second, the sound seems "continuous. Each pitch has its own duration of persistence; and "Mayer has pointed out (see Phil. Mag., 1876, vol. ii.) that in a mix- "ture of sounds, alternately admitted to the ear and shut off from it "by apertures in a rotating disc, some may be rendered evidently in- "termittent by the action of the disc, while others may appear contin- "uous, and that thus we have a new means of analyzing compound "sounds."

A. I have examined the book, and find that it contains the passage quoted in the question.

Counsel for complainant objects to all the publications in Dr. Seiler's testimony which bear date after the date of the Bell patents, in so far as they make statements which relate to facts supposed to exist before those dates, or to any matters of fact which bear upon the questions at issue in this controversy, as not competent proof of such supposed facts. Many publications have been made recently in Europe by persons interested in breaking down the Bell patents in Europe, for the purpose of affecting public opinion—as, for instance, the publication of Sylvanus Thompson, and others.

Counsel for defendants admits that the above objection is taken in due time.

Adjourned to meet Friday, April 17, 1885, at 11 o'clock, A. M.

The following was received by the Examiner after adjournment from the witness Dr. Charles M. Cresson:—

A. Yes, sir; and for the following reasons:—

First.—Because the patent sets out that method as one which will produce undulatory vibrations.

Second.—Because vocal sounds are produced by vibrations of varying frequency, with this difference, however, that the vibrations which I produced were at a slower rate per second than would produce audible sounds.

I cannot perceive what difference of result other than rate of pulse will be produced by dipping the plates twice in a second, or twenty times in a second. If these pulses will produce an audible sound, as a musical note, by causing them to dip fourteen to sixteen times in a second of time, it will be by means of similar pulses from those formed at the rate of twice in a second, that is, they will differ in no respect other than that of the rate of production, and the ability by the increased rate of vibration per second to make audible sounds.

I conclude, then, if there be any similarity between the form of electrical current and the air vibrations due to the use of undulatory currents as set out in the patent, the particular form which I produced would correspond to the air-vibrations necessary to make such musical notes as can be produced by the same number of interrupted impulses. As every vocal sound consists of musical notes of definite pitch, or rather of combinations of them, the ability to produce

TESTIMONY TAKEN ON BEHALF OF DEFENDANT.

MONDAY, April 13, 1885.

Met pursuant to notice at 11 o'clock A. M., at Dr. Charles M. Cresson's office, 417 Walnut street, in the city of Philadelphia.

Present: FURMAN SHEPPARD, ESQ., *Counsel for Respondents.*
E. N. DICKERSON, ESQ., *Counsel for Complainants.*

Dr. Charles M. Cresson, a witness produced on behalf of respondents, being duly affirmed, deposes and says as follows:—

Q 1. What is your name, age, place of business, and profession?

A. Charles M. Cresson; I am in the fifty-eighth year of my age; by profession an analytical chemist and expert in physics, and have followed this profession during a period of over thirty-three years; my place of business is at No. 417 Walnut street, Philadelphia.

Q 2. What experience have you had in the investigation of electrical devices, and what opportunities of gaining information in telegraphy and telephony?

A. I have frequently been employed in the construction and examination of various devices for electrical telegraphy and kindred purposes. My first knowledge of the electrical telegraph was acquired at the meetings of the Committee on Science and the Arts of the Franklin Institute, of which my father was for many years the chairman. An exhibition of the electrical telegraph was made before that committee, at a meeting when I was present, by Professor Morse, in the year 1838, and it was followed in succeeding years by other telegraphic exhibits, including the chemical and type telegraphs of Bain, House, and others.

Models of these various sorts of telegraphs, and of other electrical devices (such as those of Professor Robert Hare and Professor Page and Joseph Saxton), were used as illustrations at the lectures at the Franklin Institute, at which lectures I was an assistant, and took part in the preparation of the apparatus used in illustration, and in this way I became familiar with the practical manipulations required by each.

During the years from 1857 until 1876 I had occasion to repeat many of the experiments described by Professor Michael Faraday in his work entitled "Experimental Researches in Electricity." I refer chiefly to those upon the induction of electrical currents by magnets, and I have had built and used apparatus similar to that described by Faraday as used by him. I was present at the United States Centen-

nial Exhibition when the various telegraphs and telephone devices were exhibited to the Emperor of Brazil, and among other devices saw those of Gray and Bell.

During the last three years, I have devoted considerable time to the construction and examination of telephone apparatus, including that known commercially as the Bell Telephone.

I am familiar with and have experimented with the Reis device and many modern telephone instruments, and have made investigations to determine the nature and behavior of the electrical currents which are employed in the transmission of conversation through conductors of sound.

Q 3. Please state such of the general principles of sound, and of its production and propagation, as in your opinion have a bearing on the theory or on the practice of telephony?

A. To give a better understanding of the action of the air in relation to sounding bodies, and of the requirements in a device for taking up and transmitting vibrations caused in air by articulate speech, it will be necessary to advert to certain natural laws, and to explain the method by which articulate speech is produced. Much of the following material is quoted from standard authors on the subject.

Sound is invariably associated with agitation of the conveying medium; it is impossible to produce a sound without at the same time setting the medium in motion.

The motion of a material medium constitutes the mechanical impulse which falling on the ear excites within it the sensation we call sound. The rate at which sound travels varies greatly with the medium through which it travels.

The rate at which sound travels through the air is the same, whether the sound be feeble or strong, and whether the pitch be high or low. The velocity of sound in air is about eleven hundred and twenty feet per second. In a steel wire sound travels at the rate of about seventeen thousand feet in a second.

The medium through which sound passes does not share in a motion of translation; but all solid conductors remain at rest during the passage of sound, a slight yielding of their separate parts being all that their constitution generally admits of; and in fluids or in the air, with wave transmission, a continuous forward motion is equally out of the question.

The apparent movement of the particles composing the sound-conveying medium is very different from its actual motion. A cork floating upon the surface of water which is agitated into waves does

not advance with the motion of the waves, but rides over their crests and sinks into their troughs, as if it were secured in position by an anchor. Each particle of the conducting body then describes a fixed orbit of its own of very limited dimensions, a fixed oval or circular path in a vertical plane.

The propagation of all sound is therefore effected by successive forward and backward movements of the particles of the conductor, without any material change of place, and when the wave of sound has passed, there is a resumption of their original position.

Sound propagation, then, is the effect of alternate states of approximation and separation of the minute particles, which are called condensations and rarefactions, and which travel along the conducting body. When the pulse of condensation is traversing the conductor, parts of it will be more dense, and when a pulse of rarefaction is traversing it less dense, than they would be were the conductor transmitting no waves at all, and its separate particles were therefore absolutely at rest. The phenomena just described are exactly those which accompany the passage of a sound from one end of a column of air enclosed in a tube of uniform bore, and they can be produced momentarily by a single blow upon a block fitted closely in one end of the tube, or continuously by holding a vibrating tuning-fork close to the orifice of the tube. Air simply passing through a tube, or from place to place, causes no sound, but sounds that may accompany the motion of air are produced by the vibration of bodies with which it may be forcibly brought into contact.

The human voice in conversation is perpetually varying in force and in pitch, even in the pronunciation of a single sound or syllable. It has an unsteady sound.

To increase the loudness of a tone it is necessary to increase the amount of air set in vibration, and this can be done by increasing the distance traversed by the agitating body; but at the same time the period occupied in each vibration must remain the same. To increase the pitch of a tone it is necessary to increase the number of vibrations of the agitating body, that is, the vibrations must each be made in a shorter period of time.

Variations in loudness and in pitch are entirely independent of each other, and they can be combined in any desirable way.

The loudness depends solely on the extent of movement of the particles producing the sound, whilst the pitch depends solely on the number of movements made in a given period of time.

The sound produced by every vibrating body is made up to a

greater or lesser degree of composite sounds, and is an assemblage of tones, and for each series of similar vibrations they are members of a regular series forming with each other fixed intervals, and it is from this association of sounds, either by themselves or in conjunction with those produced by other vibrating bodies, that their quality or "timbre" results. By intervals we mean the relative distances by which the tones are separated from each other, distances which are indicated by the differences in the number of vibrations which produced the individual tones. The association of composite sounds is called a "clang."

The quality of a clang depends on the number, orders, and relative intensities of the partial tones by which it is composed. The tones and intensities of the individual tones of the same clang may be modified by associating with them secondary vibrations, produced by causing them to be sounded in pipes and cavities of varying forms and dimensions.

These are the chief facts that have to be borne in mind when treating of the transference of vibrations of the air. The application of this knowledge in the production of and transference of the sounds employed in articulate speech requires a consideration of the organs of speech.

The apparatus of the human voice consists essentially of vibrating chords, associated with resonant cavities. "The vocal chords are "elastic bands situated at the top of the windpipe, and separated by a "narrow slit, which opens and closes again with great exactness, as air "is forced through it from the lungs. The form and width of the slit "allow of being quickly and extensively modified by the changing ten-"sion of the vocal chords, and thus sounds widely differing from each "other in pitch, may be successively produced with surprising rapidity. "In this respect the human 'reed' far exceeds any that we can artifi-"cially construct." The size and shape of the cavity of the mouth may be altered by opening and closing the jaws, raising or dropping the tongue, and tightening or loosening the lips.

"Hence, when the vocal chords have originated a reed sound con-"taining numerous well-developed partial tones, the mouth cavity, by "throwing itself into different postures, can form, by its resonance, "first one partial tone and then another; at one moment this group of "partial tones, at another that. In this manner endless varieties of quali-"ty are rendered possible." We can detect in the lower tones of a base voice shrill overtones covering four octaves above the fundamental notes, and producing an effect upon the ear of a single musical sound.

Authorities upon sounds state that "While no two sounds of "different quality can correspond to the same mode of vibration, an "indefinitely large number of modes of vibration may give rise to a "sound of only one degree of quality. In other words, mode of "vibration determines quality, but quality does not determine mode "of vibration."

The art of speaking consists of putting into action the various movements of the mouth, so as to convert the vocal tones into words. This is effected by the aid of the lips, teeth, and tongue. The vowel sounds are formed by opening the mouth a certain distance, and breathing so as to cause the vocal chords to vibrate. Consonants are noises, or mixed clangs, and are formed very differently from the vowels; in their formation the breath first strikes upon the teeth, lips, or tongue, being held and suddenly exploded, as it were, upon the teeth, lips, or tongue, as the case may be, and followed by the vowel breathing. For example, in the word "Tea," the breath is held and forcibly expelled against the tongue and teeth, and exploded upon the vowel sound "e." In the word "Eat," the reverse movement takes place, the breathed vowel preceding the explosion which forms the "t," the ejection of breath following it giving the sound of the vowel "e." The most natural sound that is produced is "Ah," which sound is formed by partly opening the mouth, and forcibly expelling the breath. When this action is preceded by an explosive expulsion of air in which the tongue and teeth are concerned, as the means of holding the breath, the syllable "Ta" (tah) is produced, and if preceded by an explosive expulsion caused by a compression and sudden release of the lips, "Ma" (mah) or "Pa" (pah) are also produced.

The vowel sounds may be regarded as simple musical notes, produced by smooth emission of the breath, causing the vibration of the vocal chords, modified by the cavities of the mouth, but having little variation in the force or volume of the sound; whilst the consonants are formed by sounds having sudden projectile force, with entire or partial stoppage of the breath current, and with changes of tone. The percussive initiative sounds of several letters are hardly distinguishable one from the other, such as: B and P; M and N; D, T, and C; S and Z; V and F.

Articulate speech is not a continuous sound, but is a succession of sounds, entirely separated from each other by greater or lesser intervals, so that each articulation, forming part of a syllable, or separate articulate sound, endures a definite time. Faber's speaking machine made good articulate speech by means of mechanical devices that

operated at considerable intervals of time, producing a series of interrupted vibrations, or groups of vibrations separated by entire absence of vibration, or, in other words, by silence. It is evident, therefore, that a body capable of taking up and reproducing the sounds which form articulate speech, must be one in which there can be produced rapid changes in the speed of the vibrations as well as in their force.

Q 4. Referring to the Bell patent of 1876, No. 174,465, please state what you understand to be the nature and scope of said patent, and the substantial features of the contents thereof.

A. This patent is for an improvement in telegraphy. The specification says that the invention consists in the employment of

(A.) A vibratory or undulatory current of electricity in contradistinction to a merely intermittent or pulsatory current, and

(B.) Of a method of and apparatus for producing electrical undulations upon the line wire.

(C.) The characteristics of the undulatory current are set out as the result obtained from gradual changes of intensity, and as exactly analogous to the changes in the density of the air occasioned by simple pendulous vibrations.

(D.) The distinction between the undulatory and a pulsatory current is explained, and the pulsatory current is described as the result of sudden and instantaneous changes of intensity.

(E.) The advantages claimed as derived from the use of an undulatory current are:—

1. A very much larger number of signals can be transmitted simultaneously on the same circuit.

2. A closed circuit and a single main battery may be used.

3. Communication in both directions is established without the necessity for special induction coils.

4. Cable dispatches may be transmitted more rapidly than by means of an intermittent current, or by means at present in use, for as it is unnecessary to discharge the cable before a new signal can be made, the lagging of the cable signals is prevented.

5. As the circuit is never broken, a spark-arrester becomes unnecessary.

(F.) When a permanent magnet is caused to vibrate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond in rapidity of succession to the vibrations of the magnets, in polarity to the direction of the motion, and in intensity to the amplitude of its vibration.

(G.) When many transmitting instruments of different rates of vibration are simultaneously making and breaking the same circuit, the current upon the main line becomes for all practical purposes continuous.

(H.) Electrical undulations, induced by the vibration of a body capable of inductive action, can be represented graphically without error, by the same sinusoidal curve, which expresses the vibration of the inducing body itself, and the effect of its vibration upon the air.

(I.) The co-existence upon a telegraphic circuit of electrical vibrations of different pitch is manifested, not by the obliteration of the vibratory character of the current, but by peculiarities in the shapes of the electrical undulations.

(J.) There are many ways of producing undulatory currents of electricity, dependent for effect upon the vibrations or motions of bodies capable of inductive action.

(K.) When a wire through which a continuous current of electricity is passing, is caused to vibrate in the neighborhood of another wire, an undulatory current of electricity is induced in the latter.

(L.) When a cylinder upon which are arranged bar magnets is made to rotate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet.

(M.) Undulations are caused in a continuous voltaic current, by the vibrations or motion of bodies capable of inductive action, or by the vibration of the conducting wire itself in the neighborhood of such bodies.

(N.) Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit,

(O.) or by alternately increasing and diminishing the power of the battery. The internal resistance of the battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibrations of the elements of a battery, therefore, occasion an undulatory action in the voltaic current.

(P.) The external resistance may also be varied. For instance, when mercury or some other liquid forms part of a voltaic circuit then the more deeply the conducting wire is immersed in the mercury or other liquid, the less resistance does the liquid offer to the passage of the current. Hence the vibration of the conducting wire in mercury or other liquid included in the circuit, occasions undulations in the current.

(Q.) The vertical vibrations of the elements of a battery in the liquid in which they are immersed, produce an undulatory action in the current, by alternately increasing and diminishing the power of the battery.

(R.) One form of apparatus for producing electrical undulations consists of an electro-magnet having a coil upon one of its legs. A steel spring armature is firmly clamped by one extremity to the uncovered leg of the magnet, and its free end is allowed to project above the pole of the covered leg.

(S.) The armature (spring) can be set in vibration in a variety of ways, one of which is by wind, and in vibrating it produces a musical note of a certain definite pitch.

(T.) So long as the armature remains at rest no effect is produced upon the voltaic current, but the moment it is set in vibration to produce its musical note, electrical undulations traverse the circuit. The vibratory current passing through the coils of the other magnets upon the line causes vibration in the armatures of those only which are tuned in unison with that one which causes the undulations; all of the others remain silent.

(U.) The duration of the sound may be used to indicate the dot or dash of the Morse alphabet, and thus a telegraphic dispatch may be indicated by alternately interrupting and renewing the sound.

(V.) The device may also be used for the telegraphic transmission of noises or sounds of any kind.

(W.) One of the ways in which the armature "c," Fig. 5, may be set in vibration has been stated above to be by wind.

(X.) Another mode is shown in Fig. 7, whereby motion can be imparted to the armature by the human voice or by means of a musical instrument.

(Y.) The armature in Fig. 7 is fastened loosely by one extremity to the uncovered leg of the electro-magnet, and its other extremity is attached to the centre of a stretched membrane. When a sound is uttered, the membrane is set in vibration, the armature is forced to partake of the motion, and thus electrical undulations are created (upon the line circuit).

CLAIMS.

1. A system of telegraphy in which the receiver is set in vibration by the employment of undulatory currents of electricity.

2. The combination of a permanent magnet or other body capable of inductive action, with a closed circuit, so that the vibrations of the one shall occasion electrical undulations in the other or in itself.

3. The method of producing undulations in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration or motion of the conducting wire itself in the neighborhood of such bodies.

4. The method of producing undulations in a continuous voltaic circuit by gradually increasing and diminishing the resistance of the circuit, or by gradually increasing and diminishing the power of the battery.

5. The method of and apparatus for transmitting vocal or other sounds telegraphically, by causing electrical undulations similar in form to the vibrations of the air accompanying the said vocal sounds.

Q 5. What manner of currents are mentioned in said patent, and how are said currents spoken of in said patent as being generated, or modified?

A. This patent of 1876 specifies the invention to consist in the employment of a vibratory or undulatory current of electricity and of a method of and apparatus for producing electrical undulations on a line wire which is to be used for the transmission of telegraph signals. The peculiar current set out is described as one that is continuous, never to be broken, and capable of increase in force and capable of being set into vibrations at various rates. The modifications in the force or intensity of the current are to be gradual and not to be made suddenly or instantaneously.

A constant battery is to be continuously in operation through the devices and connecting wires, and changes in the intensity of the line current are to be caused by the periodical introduction into the line of other currents produced by magneto-induction, the resulting current acting magnetically upon devices which in turn produce air vibrations, yielding sounds similar to those produced by the exciting cause. The passage of the electrical current produces no sound or evidence of its presence whatever until the magneto-currents are generated by the devices provided for the purpose.

The devices are shown and described by means of which the magneto currents are created, one of which is described above in paragraph "R" and the other in paragraph "Y."

That one described in paragraph "R" has upon it a steel spring which must be set in vibration by the application of force, or, as the specification states, by wind, that is, I suppose, by blowing upon it a current of air. The vibrations of this spring produce a musical note which gradually becomes less forcible and finally fades away as the spring comes to rest.

Other springs tuned in unison with the vibrating spring (but no others) are set in vibration by the changes in the course of the current and continue sounding as long as the mechanical vibration of the first spring is continued, yielding a similar musical note which fades away to silence as does that of the spring employed to generate the first magneto current. It is stated that the "duration of the sound may "be used to indicate the dot or dash of the Morse alphabet, and thus "a telegraphic dispatch may be indicated by alternately interrupting "and renewing the sound."

There is no device shown in the drawings nor any method described or specified by which the sound can be interrupted, nor any method of starting the vibrating spring except by wind, and it is very evident that some peculiar device is rendered necessary to quickly start and stop the vibrating springs in order to enable the apparatus to be used for indicating the Morse alphabet or any other signals suitable for telegraphy.

In all of the devices that I am familiar with, a key is employed, but such a device would destroy the peculiar advantage set forth in the specification and stated in two of the claims, and with the devices arranged as they are in the drawing, a break in the continuity of the circuit would cause the battery current to cease and all of the devices would be disabled and useless.

I am at a loss to account for this omission, and cannot see that the fault can be remedied without further invention. This apparatus is therefore practically useless for telegraphy, and it is needless therefore to consider the effects of augmentation and diminution of the current of the line battery by means of the various devices referred to as suited for that purpose.

The spring upon the magnet can yield but one musical note, and, notwithstanding the provision of giving changes for loudness, can never be used to transmit articulate speech, because to do that requires an ability to give musical notes covering several octaves.

This apparatus is therefore inherently unfit for telephonic purposes in the transmission of articulate speech, as the production of a specific form of vibration, which cannot be produced by it, is necessary for that purpose.

Another device, shown in the drawing as Fig. 7, and described in the specification, and referred to above in paragraph "Y," is of entirely different character. In place of a metallic spring as a means of setting up vibratory movements, drum-heads of membrane are substituted, to which are firmly attached movable armatures to the magnets.

As the drum-head is caused to vibrate by the air impinging upon it, the keeper is caused to approach and recede from the magnet core, and thus generate magneto currents in addition to the constant current of the battery upon the line wire.

This apparatus is also to be used with the continuous current from a line battery, which current is never to be broken.

Variations in the strength of the current are in this way produced, which act upon the magnet at the receiving end of the apparatus, and cause it to attract its keeper with greater or less force, and thereby communicate motion to the drum-head to which it is attached, and in this way vibrations of the drum-head at the sending instrument produce vibrations at the receiving end of corresponding periods.

I have had the device Fig. 7 constructed in accordance with the drawing to a scale of three times larger, carefully measuring the drawing and preserving the proportions there shown.

I have not been able to transmit articulate speech by means of it, although it was tried with various changes of battery power. The source of the failure appears to me to be that the membrane has not sufficient power to rapidly overcome the inertia of the heavy keeper on the magnet, and which is attached to its centre. When we consider that vibrations to the number of one thousand per second are necessary to produce the musical notes which form the upper tones of some parts of articulate speech, and that this number may be preceded or followed suddenly by vibrations of less than one hundred to the second, it is easy to see why the feeble mechanical force of the small drum-head is unable to overcome the inertia and momentum of the keeper, which is many times its weight. If the weight of the keeper is reduced to a minimum, and the drum-head should be increased by the use of stout material, much more favorable conditions would exist, and, possibly, words could be transmitted, but imperfectly and unsatisfactorily.

An illustration of the changes in ability to move the armature which would come from such modifications can be found in the different ease of manipulation which comes from the use of a light hammer in driving a nail, for instance, and the use of a very heavy hammer for the same work, using the same length of stroke for the blow in each case. The impossibility of making the same rapid motions by each tool in equal times is a sufficient illustration and argument to explain why the Fig. 7 of this patent is unable to take up or give out vibratory impressions at the rapid rate necessary for the reception and reproduction of articulate speech.

It must not be forgotten that the motions of the receiving diaphragm are not nearly so great nor so forcible as those of the transmitter. This depreciation in effect comes chiefly from the defects of the mechanical contrivances.

The history of telephony shows that instruments of this character have never come into practical use for any purposes whatever; and there is no record that I have seen that they have successfully transmitted connected articulate speech.

If this device was of proper mechanical construction there is no doubt but that to some degree the transmission of articulate speech could be effected, but very imperfectly at best; in this case not only changes of tone (pitch) but those of force (amplitude) would be effected.

The suggestion that articulate speech could be transmitted by any of the devices of this patent does not appear in the specification or claims, but it is stated that in Fig. 7 motion can be imparted by the human voice, or by means of a musical instrument; this association of a musical instrument with the human voice, together with the fact that no means for starting or stopping the vibratory action of the reeds are shown or suggested, and the fact that the production of musical notes, singly or in combination, is alone referred to, leads me to the conclusion that the inventor did not intend the apparatus to be used for any other purpose, and the preamble of the patent No. 186,787, of 1877, confirms me in this opinion, because it sets out that in this patent, as well as that of 1875, "A separate instrument is there-" fore employed for every pitch."

I conclude, therefore, that this device cannot be included among those that are useful, except perhaps for the transmission of single tones; nor does it appear to have in any way ever been used so as to approach in its results the performances of the Reis "telephone," which has so often been referred to in the discussion of sounds, musical tones, and articulate speech.

Q 6. Please refer to the Bell patent of 1877, No. 186,787, and state what you understand to be the nature and scope thereof and the general features of its contents.

A. This patent is for an improvement in telegraphy. The patentee says his invention has for its object,

(AA.) First, the transmission, simultaneously, of two or more musical notes or telegraphic signals along a single wire in either or both directions and with a single battery, without the use of as many instruments as there are musical notes or telegraphic signals to be transmitted.

(BB.) Second, the electrical transmission, by the same means, of articulate speech and sound of every kind, whether musical or not.

(CC.) Third, the electrical transmission of musical tones, articulate speech, or sounds of every kind, without the necessity of using a voltaic battery.

(DD.) For the membrane and armature shown in the transmitting and receiving instruments of the patent of 1876, is substituted a plate of iron or steel, capable of being thrown into vibration by sounds made in its neighborhood.

(EE.) The plate of iron or steel is fastened at its edges to the sounding-box, and a speaking-tube enters the side of the box next to the plate at its centre. A soft-iron core is surrounded by a coil of insulated wire placed near to one end of the core, and an adjusting screw is connected to the core carrier, whereby the distance of the end of the core from the plate of iron may be regulated.

The coil of insulated wire is connected in a line circuit with a battery upon it.

(FF.) This instrument may be used both as a transmitter and as a receiver.

(GG.) Another form of telephone for use without a battery is shown in Fig. 5, a compound permanent magnet, to the poles of which are affixed poll-pieces of soft iron surrounded by helices of insulated wire.

(HH.) In lieu of the iron plates, iron or steel reeds of definite pitch may be placed in front of the electro-magnets and the battery omitted in the line circuit.

(II.) The essential feature of the invention consists in the armature of the receiving instrument being vibrated by the varying attraction of the electro-magnets, so as to vibrate the air in the vicinity thereof in the same manner as the air is vibrated at the other end by the production of the sound.

(JJ.) Any instrument receiving and transmitting the impression of agitated air may be used as a transmitter.

(KK.) It is important that the distance of the magnet from the plate should be as little as possible, without however being in contact.

(LL.) The electrical undulations produced upon the main line by the vibrations of the plate are intensified by placing the coil at the end of the bar nearest the plate, and not extended beyond the middle or thereabouts.

CLAIMS.

1. The union upon, and by means of, an electric circuit, of two or

more instruments, so that, if motion of any kind or form be produced in any way in the armature of any one of the said instruments, the armatures of all the other instruments upon the same circuit will be moved in like manner and form, and if such motion be produced by sound, like sounds would be produced by the motion of the latter.

2. In a system of connected transmitting and receiving instruments upon an electric circuit, the production in the armature of each receiving instrument, of any given motion, by subjecting the said armature to an attraction varying in intensity.

The production of any given sound or sounds from the armature of the receiving instrument, by subjecting the said armature to an attraction varying in intensity, in such manner as to throw the armature into that form of vibration that characterizes the given sound or sounds.

3. The combination with an electro-magnet of a plate of iron or steel or other material capable of inductive action, which can be thrown into vibration by the movement of surrounding air or by the attraction of a magnet.

4. In combination with the plate and electro-magnet, the means herein described, or their mechanical equivalents, of adjusting the relative position of the two, so that they may be set together as closely as possible.

5. The formation, in an electric telephone such as is herein shown and described, of a magnet with a coil upon the end or ends of the magnet nearest the plate.

6. The combination, with an electric telephone such as described, of a sounding-box.

7. In combination with an electric telephone, the employment of the speaking or hearing tube for conveying sounds to or from the telephone.

8. In a system of electric telephony, the combination of a permanent magnet with a plate of iron or steel or other material capable of inductive action, with coils upon the end or ends of said magnet nearest the plate.

Q 7. What do you understand to be the general sense of this patent and the general character of the devices contained in it, as compared with the patent and the devices of 1876?

A. In the specification of this patent is a statement that the former patents to Mr. Bell, No. 161,739, of 1875, and No. 174,465, of 1876, respectively, set out a method and apparatus for the pro-

duction of musical tones by the action of a rapidly interrupted electrical current, and for the production of musical tones by the action of undulatory currents, and that a single battery may be used for the whole circuit.

In the apparatus referred to in both of the former patents, a separate instrument is employed for every pitch, each instrument being capable of transmitting or receiving but a single note, and thus as many separate instruments are required as there are messages or musical notes to be transmitted.

The invention described in this patent is included in the specification under three heads, the first of which refers to the transmission simultaneously of several individual musical notes or sounds through a single wire and with a single battery, without the use of as many instruments as there are musical notes to be transmitted. This clause introduces a single device which is intended to transmit more than one musical note at the same time, and the specification says: "In ac- "cordance with my present invention I substitute for the membrane "and armature shown in the transmitting and receiving instruments"— "A plate of iron or steel capable of being thrown into vibration by "sounds made in its neighborhood."

In other words, this change in the device No. 7 of the patent of 1876 is the substitution of a plate of iron or steel for a membrane. The functions of the membrane were to receive and transmit mechanically, air vibrations thrown against it. The plate which is substituted is (as the specification indicates) to be "capable of being thrown into "vibration by sounds made in its neighborhood." That is, to perform a similar function as did the thing for which it was substituted.

Examination of the drawing and description, however, shows that this "substitute" also performs other functions foreign to the element for which it was substituted.

This plate takes the place of the membrane, armature, and connecting link combined, and it also performs functions which are entirely foreign to the original device and which had no existence in that invention or device, to wit, the substituted plate acts as a receiving "sounding-board," which in itself includes a vibration damper wherein vibrations cease as soon as the inciting causes cease, whereby sudden changes in vibratory conditions can be made, which enable a rapid succession of otherwise incompatible vibrations to be received and communicated. This property of receiving, damping, and again quickly receiving vibrations, is not possessed by the spring armatures of the devices of the 1876 patent, nor by the combined membranous dia-

phragms and armatures of the device shown in the drawing as No. 7 of the patent of 1876.

In other words, the element substituted in the patent of 1877 as an improvement upon the patent of 1876 is not an equivalent, but possesses another and peculiar and specific attribute not found in the original device or combination of devices which it replaces.

The second head set out as to the object of the new invention relates to "the electrical transmission by the same means of articulate "speech and sound of every kind, whether musical or not."

The power which the device of this patent possesses of transmitting articulate speech depends upon and is acquired solely by the substitution of the iron or steel plate referred to in place of the membrane and loose armature, and especially and alone upon that additional property which I have stated did not exist in the device or devices for which it was substituted as an improvement.

The third head set out as to the objects of the new invention relates to the "electrical transmission of musical tones, articulate "speech, or sounds of every kind, without the necessity of a voltaic "battery."

In this method of operation, the new property or qualification introduced by the substitution of the plate is of prime importance so far as articulate speech is concerned. The extreme feebleness of the results obtained in this way of working without any aid from the voltaic battery current, has prevented the useful application of the devices for the ordinary purposes in which it is desirable to transmit articulate speech.

In fact, this modified instrument is not now used at all as a transmitting device, but it is used at the receiving end of telephone lines for the purpose of converting the electrical impulses into sound, but not in the manner set out in the patent.

In addition to the substitution of an iron plate for the membrane of the device of Fig. 7, a closed box has been substituted for the cone, and of such dimensions that the magnet and coil and plate are all contained within it, and the magnet is provided with an adjusting screw by which its distance from the plate can be regulated at will. This adjusting screw and its adjuncts are similar to those employed in the older dial telegraph boxes of 1858 to 1885, and used for adjusting the distance of the magnet from its keeper, and it is used also upon many relay magnets working upon ordinary telegraph lines.

A speaking (and listening) tube is fitted to the side of the box by

means of which the sounds to be transmitted are caused to impinge upon the centre of the iron plate.

This speaking-tube resembles that employed by Reis in 1865, with this difference, however, that in the Reis device the sounds are directed into the body of the box and then deflected upon the diaphragm of the transmitter.

Another form of telephone for use without a battery is shown, in which a compound magnet, to the poles of which are affixed poll-pieces of soft iron surrounded by helices of insulated wire, replace the single bar magnet in the telephone box.

This magnet with its keeper is practically a copy of the Hughes polarized relay, which is thus described in the work entitled "The "Electric Telegraph, by Robert Sabine, London, 1867," p. 61. "It "consists of a permanent horseshoe magnet, with soft-iron cylindrical "continuations in the poles."

These continuations are each encircled by a coil of wire, the armature is attracted to the poles by the magnetism distributed in the iron. This force is opposed by the adjusting spring, which is so regulated that, the armature being in contact, a very weak current is able to neutralize the attraction. This magnet is used to receive electrical impulses from a distant station, and by its action regulate the movements of a printing device. When connected to a telephone line as a receiver, it renders articulate speech spoken into the transmitter equally as well as the ordinary Bell receiver. By a comparison of the description of the Hughes relay just quoted with the description of the compound permanent magnet given upon page 2 of the Bell patent of 1877, and with the drawing attached to the patent, the identity of the essential parts of the two devices cannot escape notice. "The essential "feature of the invention" of Bell is quoted in the paragraph above, "II," and it is found in the Hughes relay of 1867 as well as in the Bell device of 1877.

In the Reis receiver No. 2, which consists of an electro-magnet resting upon a sounding-board, the surrounding coils of which are connected with the metallic circuit leading from the transmitting device, there stands opposite and near to the ends of the magnet cores an armature or plate of iron, which performs to a degree the same functions as does the iron plate of the device of the Bell patent of 1877.

In Kuhn's Handbook of Applied Electricity, 1865, pages 1017–1021, the following statement is found: "In respect to the operations "of this apparatus, the author remarks that the receiver does pro-"duce the exact number of the original vibrations, but that a repro-

"duction of the original intensity had not yet been attained. For "that reason, it is added, small differences in the vibrations are appre- "ciated with difficulty, and in the practical experiments made thus far it "was possible to transmit with astonishing faithfulness chords, airs, &c., "whilst in reading, speaking, &c., single words were more indistinctly "heard."

The facts set out in this paragraph also show that the Reis receiver No. 2 possessed, to a degree at least, the "essential features of the in- "vention" of Bell's patent of 1877.

In the work entitled "Electricity and Magnetism," by Fleeming Jenkin, London, 1880, and upon pages 375, 376, and 377 are the following statements in reference to the Bell magneto-transmitter and receiver, and their relative movements: "The movements will be "proportional to one another, but very far from equal; that of the "sending disc will be immensely greater than that of the receiving "disc."

"It has been discovered that instead of a thin ferrotype disc of iron "a thick plate might be used." "A far more singular fact has been "discovered by many observers, namely, that non-magnetic and even "non-conducting substances might be used instead of a ferrotype disc "in the receiving instrument: and lastly, that the receiving instrument "will work, though very feebly, with no disc whatever." "In this case "it seems clear that the Page effect, as it may be called, *i. e.*, the noise "made by the magnet itself as its particles re-arrange themselves with "each change of stress, is the source of the sound heard."

The receiver (No. 1) of Reis, which consists essentially of a thick iron needle wound over with a spiral of insulated wire (the whole being supported upon a resonator), contains the same essential parts as does the Bell receiver described in the patent of 1877, excepting only the iron disc, or armature; and if the statements just quoted from Fleeming Jenkin's book are correct, the parts of the Reis receiver performed precisely the same functions as do the similar parts of the Bell device.

The method of placing the coil at the end of the magnet bar is referred to in the "Proceedings of a Monthly Meeting of the Franklin "Institute, held at Philadelphia, November 21st, 1861," and printed in the Journal of the Institute, volume 42, p. 420.

It is there stated that it was constructed by Dr. Van der Weyde, of New York. The record contains the following comment: "This ar- "rangement (which I find to have been already made in France some "four years ago) has two defects:—

"1. That the whole magnetic power of the steel is not taken ad-"vantage of, by winding alone the extremities."

The device referred to was constructed for the purpose of comparing the results obtained with other magnets differently wound, to determine how "to arrange a given quantity of steel, so as to obtain "the strongest permanent magnetism, and to arrange a given quantity "of insulated copper wire, so as to obtain, by that magnetism put in "motion, the greatest amount of electricity." The result obtained by this arrangement of the coil does not coincide with that specified in Bell's patent of 1877.

The device is especially referred to in the fifth claim, and forms a part of the subject-matter of the eighth claim.

The subject of the first claim is so broadly stated, that it appears to me to cover all ordinary relay instruments in use on telegraph lines, as well as the devices for producing musical notes specified and claimed in the patents of 1875, and the first device shown in the patent of 1876. For in each case, if motion of any kind or form be produced in the armature of one of two instruments upon the same circuit, the armature of the other will be moved in like manner. It is true that the design of the devices of the patents of 1875, and the first device of that of 1876, is that but two instruments shall be tuned in unison, but it is likewise a fact that if it is so desired, many instruments upon the same line may be made to vibrate in unison with or in response to one instrument which initiates the vibratory movements. Any number of instruments can all be tuned in unison, and will to that greater degree conform to the operations described in the claim of the earlier patents.

The subject-matter of the second claim seems in like manner to be anticipated in the device of the patent of 1876; the object of the first device of that patent being to produce attractions varying in intensity.

Similar comment is applicable to the subject-matter of the third claim, as the inductive effect of the spring plate of iron or steel of the first device of the patent of 1876 is very exactly described in this claim.

The device described in the fourth claim has already been referred to as a usual method of adjusting the relative positions of a magnet and its armature, and the device was introduced by me into dial telegraph instruments before the year 1859.

The subject-matter of the eighth claim was fairly described in an article upon "An Application of Magneto-Electricity by Sir Charles "Wheatstone," printed in the *Telegraphic Journal and Electrical*

Review, London, November, 1872—November, 1873, vol. 1, and on p. 4. It is true that the device is not applied to telephonic purposes, but it exhibits the "combination of a permanent magnet with a "plate of iron or steel, or other material capable of inductive action, "with coils upon the ends of the magnet nearest the plate." It is likewise a fact that although the coils are upon the ends of the magnet they preserve their axes at right angles to the axis of the magnet bar, but this arrangement does not in any way affect the inductive action desired.

It will also be observed that the induced currents which follow each other and proceed in opposite directions, make a complete vibratory movement at each use of the machine, and that both currents are used in turn. The description is as follows, and the device is illustrated by an engraving:—

"On reference to Fig. 1 it will be seen that the essentials of the "apparatus are a small permanent magnet, two coils of fine wire with "soft-iron cores, and an armature of soft iron. The spring to which "the armature is attached presses the armature against the soft-iron "cores of the bobbins maintaining the strength of the magnet when the "apparatus is not in use. When by pressure on the lever the armature "is quickly removed from the poles of the magnet, a current is in-"duced in the coils of wire, and is communicated by leading wires to "the register or indicator, Fig. 2, where it acts by means of an electro-"magnet upon a step-by-step motion precisely similar to the motion "imparted to the needle of the receiving instrument of the A. B. C. "telegraph. On the return of the armature into contact with the soft "iron prolongations of the permanent magnet a current is generated "in an opposite direction to the first. The first current causes the "hand of the indicator to advance half the distance between two of "the figures upon the dial, the second current completes the move-"ment, and records one action of the machine to which the apparatus "may be attached."

Q 8. State whether you have examined the telephonic devices used by the defendant company, and if so, please describe the same.

A. I examined the instruments marked in this suit "Exhibit Defendants' Transmitter" and "Exhibit Defendants' Receiver" before they were delivered to the counsel for the complainant, and have in my possession duplicates of the same.

The "Exhibit Defendants' Transmitter" consists of a cubical box with a hinged door upon the front. The central portion of the door being formed by a thin panel of wood. This panel is in fact a wooden

sounding-board, in front of which is placed a shallow panel-shaped block pierced with a central opening about an inch and a half in diameter.

The panel is placed about half an inch distant from and in front of the sounding board, and in fact forms a mouth-piece, through the central opening of which the sounding-board receives its vibratory impressions.

A pin carried upon a metal spring bears upon the surface of the sounding-board opposite to the centre of the mouth-piece, and acts as a damper to deaden the vibrations and limit their continuance. Upon the inside of the panel and opposite to the centre of the mouth-piece, which is on the outside of the panel, is fixed a platinum wire.

A soft-iron rod about three-sixteenths inch in diameter, upon which is secured a small induction coil, is suspended from a bracket fixed centrally near the top of the inside of the door. To the side of the induction coil is fastened a rod of carbon, so located as to bear upon the platinum wire on the sounding-board. The iron suspension rod which carries the coil passes through and projects beyond the lower end of the coil, and is there brought near to a piece of iron which is secured between the rod and the sounding-board. When a current of electricity passes through the coil the suspending rod becomes magnetic and is attracted to the piece of iron, and by that attraction the carbon rod is pressed against the platinum wire upon the sounding-board. The action of gravity also tends to keep the carbon rod and the platinum wire in contact. In a compartment beneath the cubical box which contains the induction coil is placed a cell of galvanic battery. Wire connections are carried from one pole of the battery to one end of the primary coil of the induction coil, and from the other end of the primary coil to the carbon rod which is secured to the outside of the induction coil. From the other pole of the battery a wire connection is carried to the platinum wire which is secured on the sounding-board. Contact between the platinum wire and the carbon rod completes the electric circuit, and a constant current from the battery is maintained until a vibration of the sounding-board is produced, which disturbs the relationship of the platinum wire and carbon rod. This portion of the apparatus covers the device of the defendants' transmitter.

The secondary wire upon the induction coil is connected at one end to the earth, or to a wire leading to another station, whilst the other end of the secondary coil wire is led to the receiving station, and there through the receiver, and then to earth, or some connection

which completes electrically a circuit in which the secondary coil of the induction coil and the receiving instruments are included. It is to be observed that the continuous battery current is limited to the circuit of the transmitting device, and that at no time is there a battery current sent upon the line wire which connects the telephone stations with each other.

I find in connection with this transmitting device a magneto call-bell and a dynamo machine for producing at will an electrical current for the purpose of calling the attention of the distant station by means of a magneto call-bell there located. These devices are isolated from the line wire circuit by means of switches whenever the transmitter is to be used.

The " Exhibit Defendants' Receiver" consists of a tri-polar permament magnet, the two outer poles of which are of a similar nature, and of opposite nature to the central pole. The three poles are wound with insulated wire of small diameter, and in such direction as to maintain, with a proper current, the magnetic relationship of the poles of the magnets. The two outer poles are united near their ends by an annular iron diaphragm. Upon this diaphragm is fitted a thin cupped disc diaphragm, made also of iron.

The central pole is insulated from the side poles and from contact with the annular diaphragm, and is prevented from touching the cup diaphragm, which covers the end of the receiver. The ends of the wire coils which surround the poles of the permanent magnets are carried through the case of the instrument, and form the connections, one with the line wire leading to another station, and the other to the ground, or to some connection whereby the circuit is completed, including the receiver and the secondary wire of the distant transmitter. The result of this construction is that the cup diaphragm becomes of similar polarity to the outer poles of the permanent magnet, and is of opposite nature to that of the central pole.

Q 9. Have you made any observations or experiments with reference to the nature or action of the currents passing through the apparatus of the defendant, and if so, will you state the results thereof?

A. Upon examination I fail to find any current in the line wire connecting the transmitter with the receiver, except when the contact between the platinum rod upon the sounding-board, and the carbon rod which is normally pressed against it, is disturbed.

When the contact between the wire and rod was disturbed, I found that currents passed through the wire. When conversation was carried on through the instruments and connecting wire, a succession of

short disconnected currents passed through the wire, and when the syllables or phonetic sounds were slowly enunciated the impression of each group of impulses was very evident.

These results were obtained and verified first by observations with a galvanometer, which clearly indicated the passage of disconnected currents; and second, by observations upon the motions of an indicating pendulum pointer attached to the keeper of a delicate electromagnet which was included in the circuit of the line wire. These observations were made during the transmission of conversation and without any interruption of the passage of articulate speech, and they show that the normal condition of the current in the line wire when in use, is one of discontinuity or disconnection, and not of continuity.

The passage of these disconnected currents indicates and proves clearly, to my mind, the occurrence of minute and rapid breaks in the continuity of the local current in the transmitting device.

To determine this I made many experiments with induction coils, in the primary coils of which, constant currents of varying quantity were passing, and in no instance did I obtain a current in the secondary coil except when a break of contact occurred in the current passing through the primary coil. In fact, there is no reason why in the transmission of articulate speech that breaks in the current should interfere, provided always that the duration of the break shall be of such short period that contact is made in time to receive the next impression or vibratory movement.

That such is the fact, can be proved by using the local connections of an ordinary relay magnet as a transmitting instrument. In doing this it is necessary to adjust the contact points of the local circuit very closely, and to connect the local poles of the relay to the primary wires of an induction coil in the place of an ordinary transmitter. By turning the instrument upside down (so that the lever of the keeper shall swing as a pendulum), and talking against it, conversation can be readily and successfully transmitted. In this experiment the magnets and coils surrounding them are not used, and really form no part of the apparatus in service.

Whatever may be the supposed theoretical conditions of the telephonic transmission of speech, including among other conditions that of continuity of current, I am of the opinion that such continuity is practically non-essential. My reasons for such opinion are, in part, derived from the fact that there is a persistence of auditions which maintains or prolongs or carries forward the sensation of hearing in the organ, without taking conscious notice of gaps or interruptions of

continuity, within certain limits, just as the eye takes no conscious notice of the obstruction or exclusion of external objects occasioned by the act of winking; and also from the fact, as I believe it to be, that when words or sentences are spoken into the transmitter, and received at the receiver, they are apprehended by the ear at the receiver not according to the letters which constitute them, or according to the syllables which constitute them, or according to the words in their entirety. Instead of being a transmission by letters or syllables or words, it is rather a phonetic transmission which takes place.

The leading sounds are caught up by the ear; connections of a sound are anticipated, or are supplied automatically, or are perhaps overlooked. A single sound, especially of a predominating one, may be the key-note or the representative of an entire word. I think this becomes more and more evident to a person in proportion as his experience with telephonic instruments increases, and as his ear becomes more and more educated to the use of the instrument.

Q 10. Please compare the defendants' devices and those of the plaintiff, with reference to question of infringement, and state what in your opinion and belief are the results of such comparison?

A. A comparison of the "defendants' transmitter" and method of using it with the devices of the plaintiff's patents does not reveal the use of any of the devices described in the specification, or set forth in the claims of the patent of 1876.

The "defendants' transmitter" does not contain magnets, either of the electro or permanent form (in combination with a closed circuit), the armatures of which are set in vibration by inductive action, so that the vibration of one shall occasion electrical undulations in the other or in itself, as set forth in the second claim of the patent; nor does the complainants' transmitter employ the method of producing undulations in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration or motion of the conducting wire itself in the neighborhood of such bodies, as is set forth in the third claim of the said patent.

Nor does the plaintiff in his transmitter make use of a method of producing undulations in a continuous voltaic circuit by gradually increasing or diminishing the resistance of the circuit, or by gradually increasing or diminishing the power of the battery, as set forth in the fourth claim of said patent.

Nor does the transmitter of the defendant contain any of the apparatus, nor the equivalent of the apparatus described in this patent for transmitting vocal or other sounds telegraphically, nor does it de-

pend for its action upon the method of operation which is set forth in the fifth claim of the complainants' patent.

In fact the transmitting device of the defendant does not employ or even contain any permanent or electro-magnet used for inductive purposes, whereby the current in a closed circuit is set in "undulatory" vibration.

Nor do the defendants use a receiver which is set in vibration by the employment of "undulatory" currents of electricity, in the manner set forth in the first claim of the patent and described in the specification.

A comparison of the defendants' transmitter with the devices of the complainants' patent of 1877 shows it does not contain the device referred to in the first or second claims, as it does not contain "an instrument" having an armature, as do those referred to in the said claims.

It does not contain the device set out in the third, fourth, and fifth or eighth claims, because it does not contain an electro, or a permanent magnet for producing inductive vibrations in a closed circuit.

The defendants' receiver is not united by means of an electric circuit with any transmitting instrument, nor is it subjected to attractions of varying intensity, so that it is not included in the devices set out in the first and second claims.

As it does not contain an electro-magnet nor any means for adjusting the relative position of a magnet and its armature, nor the sounding-box, nor the speaking or hearing tube, it is not to be included with the devices of the third, fourth, sixth, or seventh claims.

The magnet in the receiver has a coil upon the end or ends of the magnet nearest the plate or armature, such as is set out in the fifth claim, that is, in the manner shown and described in the proceedings of the Franklin Institute before referred to, and it is a permanent magnet in combination with a plate of iron, with coils on the ends of the said magnet, as set out in the eighth claim, and as is shown in the Hughes relay and in the Wheatstone apparatus, both already referred to; and the latter apparatus was constructed and was used for producing electric currents by induction in a circuit which was never broken by changing the relative position of the magnet and the plate, and this current, which first passed in one direction and then in the other (by replacing the plate), was passed through the coils of an electro-magnet to give motion to its armature.

The defendants' receiver does not respond to permanent currents in which the intensity of the current is gradually changed, that is,

currents that are converted into an "undulatory" current by increasing or diminishing the power of the battery; nor does it respond even when connected through the secondary coil of an induction coil through which an undulatory current from a battery is passing. For these further reasons it appears to me in every way to fail to be described in the specifications of either the patent of 1876 or that of 1877.

The method of operation of the defendants' transmitter is similar to that of the Reis, that is, the vibrations of the diaphragm cause rapid breaks and makes in an electric circuit in which is placed a constant battery. The substitution of carbon for one platinum electrode in the Clay device enables the circuit to be opened to a wider extent before the current is interrupted, and in that way prevents too great prolongation of the time during which the circuit is broken. By tilting the Reis transmitter so as to present the upper surface at an angle to the horizon, the pounding of the spike upon the flat electrode is prevented, and an induction coil used in the usual way, it will without further change transmit articulate speech. If a carbon electrode is substituted for the spike and an induction coil used in the usual way, the instrument will then serve as a good transmitter for ordinary service.

The contact of the electrodes in the Reis transmitter is effected by gravity, that of the electrodes in the defendants' device chiefly by gravity and to a limited extent by magnetic attraction in addition.

That the defendants' transmitter works by using an intermittent current has been before stated, and the reasons for that opinion have been given. It may be further stated that unless the local battery current is actually broken by the separation of the electrodes there is no transmission of sound by defendants' device. In this respect it differs essentially and distinctively from the method of operation described and claimed as the peculiar invention which is covered by Mr. Bell's patents of 1876 and 1877, which patents not only specifically describe a peculiar undulatory current, but contrast it with intermittent and pulsatory currents as not being of that character, but being free from interruptions and sudden changes of intensity.

In former suits the Reis device has been rejected as antedating the Bell on account of its make and break character, but it is evident that it does antedate the defendants' device in that respect on account of the similarity of action of the two devices, both being of the so-called make and break circuit mode of operation.

I am therefore very clearly of the opinion and belief that the defendants' devices are no infringement of those of the patentee, unless

indeed the mere act or fact of transmitting articulate speech, wholly irrespective of the means, or method, or apparatus of transmission, constitutes an infringement. As respects the means, method, and apparatus, I am of the opinion and the belief that those employed by the defendant are entirely different from those employed by the patentee, and as respects the method, operation, or process employed and the action and nature of the currents involved, there is also an essential difference and dissimilarity.

I may add that I do not find in the evidence on behalf of the plaintiff anything to show that the current which passes along the line wire in the defendants' devices, and whereby speech is transmitted, is an undulatory current as contradistinguished from a pulsatory current, nor do I know of any means by which it can be shown that such is the case. To say that the current is undulatory and not pulsatory and not intermittent, merely because speech is transmitted, seems to me to be inconsequential and to be contrary to, or at least without support from, our knowledge on the subject. The theory of the electrical transmission of speech, and of the action of telephonic devices, is still undetermined, and various opinions on the subject are entertained by very high authorities in this branch of knowledge. The term "current" as applied to electrical action is itself little more than a mere figure of speech, and divisions and subdivisions, as respects the different forms and characteristics of currents, are mere assumptions which cannot be shown, or at least have not yet been shown, to have an actual counterpart in nature.

MONDAY, April 13, 1885.

Cross-examination of Dr. Charles M. Cresson by E. N. DICKERSON, Esq., Counsel for Complainants:—

× Q 1. Did not the exhibition of Professor Bell's telephone at the Centennial, to a company of scientific gentlemen of which you were one, elicit the expression of great astonishment and admiration at the time of the exhibition, and afterwards?

A. Yes, sir; it was considered to be a wonderful exhibition. I was not present as one of the examiners, and took no further part than to listen to the explanations, and to endeavor to obtain an idea of the apparatus and its workings. My especial attention was directed to the apparatus of Mr. Gray rather than that of Mr. Bell, as then I

had no idea of the value of the ability to transmit speech as compared with the telegraph of Mr. Gray, in which I was interested, as a means of enlarging telegraph facilities.

× Q 2. The Bell's transmitters on that occasion had membrane diaphragms to the centre of which iron armatures were attached, did they not?

A. That is my recollection of them. Not that they were like Fig. 7 of the patent, but differed from that arrangement, in that the armatures were simply attached to the membrane without a connecting link to any fixed point. After this lapse of time I cannot definitely describe it, but such is my present recollection of the construction of the apparatus.

× Q 3. But those instruments with membrane diaphragms and armatures attached to them did talk in your presence, did they not?

A. I did not hear them talk, but understood that words had been transmitted; I don't mean connected conversation, but isolated words spoken into the transmitter were heard at the receiving end. It was a subject of discussion among those present.

× Q 4. Do you mean to say to the court, that on that Sunday when you were present and the Emperor of Brazil and Sir William Thompson, the telephone did not transmit sentences read from newspapers or quoted from Shakespeare, as appears stated in the report on awards, Group XXV., Centennial Exhibition, pp. 130 and 131?

A. No, sir; not by any means. What I do say is I did not hear the telephone speak, and that by my conversation with those around I understood that words had been transmitted. As I before observed, my attention was chiefly directed to another exhibit, and I made no effort to become an observer of what was done with the Bell apparatus except as to inquiring what was the result of the use of the apparatus, as a matter of scientific interest.

× Q 5. The Bell exhibit was in a different part of the building from the Gray, and the exhibition was subsequently to that of the Gray, was it not?

A. In my recollection the Bell exhibit was in the Main Building on the eastern side near the end next to Machinery Hall, whilst the Gray exhibit was near the middle of the same building, but on the west side of the main aisle. The relative time of exhibition I do not remember.

× Q 6. In both Fig. 7 and in the Centennial instruments the armatures were fastened to the membrane diaphragm at the centre of it, so that the diaphragm and armature must move in unison? Is not that so?

A. Yes, sir; but the armature in Fig. 7 is connected to a fixed point by a loose link, also to the membrane by a fixed stud, whilst in the Centennial arrangement, my recollection is, that the armature was secured to the centre of the membrane without other attachment.

(The model of Fig. 7 produced by the witness on his direct examination is now offered by the complainant in evidence, and marked "Cresson Fig. 7.")

× Q 7. In the model of Fig. 7 which you have made you have removed the face of the armature from the pole of the magnet a very long distance, say nearly an eighth of an inch, which you did, as I understand your statement, by carrying out the proportions of the lithograph drawing in the patent, both in respect to the size of the instrument and in the distance apart of the armature and magnet. Now, as an electrician, did you not know before you tried the experiment that when that armature was thus far removed from the magnet the magnetic force would be diminished as the square of the distance increased, and that it would be impossible for the feeble currents generated in the telephone to make the magnet operative through so great a distance?

A. The model of Fig. 7 was constructed to a scale, and the distance of the magnet and keeper were fixed upon the same scale. I was of the opinion that the distance was too great for the production of any good result.

The models were constructed in this way, for the purpose of having an accurate copy of the apparatus set out, and as no mention is made in the patent of 1876 of the necessity for a close adjustment of the armature and magnet, and as the patent of 1877 first sets out, "that "the distance of the magnet from the plate should be as little as "possible," I concluded that the matter of distance was not understood to be material by the patentee in 1876, and consequently the representation of Fig. 7 was what he intended it to be, and so made it.

Notwithstanding the wide separation of the magnet and armature, the magnetic attraction produced by the use of two cells of Grenet battery causes the diaphragm to be drawn tightly towards the magnets.

For the reasons given, I did not feel warranted in making a change whereby the distance between the armature and magnet should be diminished.

If this is done, one of the causes of the failure of No. 7 to produce responsive vibrations of the diaphragms will be removed.

× Q 8. Was it not a matter of familiar knowledge by electricians in 1876 that in telegraph devices, in which a magnet and armature were used to indicate the presence and absence of electrical currents, the armature should be brought up as close as possible to the magnet in order to obtain the best effect; and was it not well known in that class of instruments that adjustments of the distance between the armature and magnet were generally provided in order that the operator might set the distances at the efficient point?

A. As respects the use of magnets for ordinary telegraphic purposes, that is, upon a circuit which was alternately made and broken, it was well understood in 1876 that the adjustment of magnet and armature was of great importance to secure the best results. The use of a line with magnets and armatures worked by a continuous, unbroken battery current, which current was to be modified by induction, was a novelty, and introduced new features before unknown. The fact that the continuity of the line was never to be broken and that the magnets did not at any time cease to attract their armatures would, to my mind, have diminished if not removed the necessity of such adjustments.

I do not think that the necessity for similar provisions as those used for ordinary relay magnets occurred even to Mr. Bell until experiment and trial showed him the necessity for it.

× Q 9. Did you not know that in Fig. 7 the battery current itself, which you say is adequate to sufficiently magnetize the magnets to attract the armature at this great distance, is not the efficient cause of the vibrations which are to transmit speech, but that the extremely feeble magneto current is the efficient cause, and that therefore it is peculiarly necessary to place the armature as close as possible to the magnet in order to feel the influence of that feeble current; and knowing that as an electrician, do you suppose that Professor Bell was ignorant of it and did not know that the further off the armature was placed the less effect he would get from this feeble current?

(The witness states that he has now been under cross-examination for three hours, and is physically unable to proceed further to-day.)

Adjourned to meet Tuesday, April 14, 1885, at 10.30 o'clock.

TUESDAY, April 14, 1885.

Met pursuant to adjournment at 10.30 o'clock A. M.

The cross-examination of Dr. Charles M. Cresson is resumed:—

A. I am aware that the battery current varied by the momentary superposition of feeble magneto currents which at times increase and others decrease its intensity, is the agent by which the armatures are attracted with greater or lesser force. But I am not aware that the relative values of the two currents used in that way were known to electricians, for I did not know of the necessity for such close adjustments as is required until after experiment with telephones under various conditions.

× Q 10. In your direct examination you said "if the weight of the "keeper is reduced to a minimum and the drum-head should be in-"creased by the use of stout material, much more favorable condi-"tions would exist;" you also have said that you had your model of Fig. 7 made by "carefully measuring the drawing and preserving the "proportions there shown." I now call your attention to the fact that the membrane *a* of the drawing is shown as thick as the armatures, so far as one can judge without resorting to micrometrical measurements; but that in your supposed Chinese copy of the drawing the membrane, instead of being increased in thickness in proportion to the increased size to which you have expanded the apparatus, and therefore made about as thick as the armature itself, is extremely attenuated, and certainly fifty times thinner than the armature. Now will you explain why, when you knew that it would improve the operation of the instrument to increase the thickness of the drum-head by use of stout material, you diminished its thickness far below that shown in the drawing, while you increased the weight of the armature and the distance between the magnet and the armature?

A. My answer in direct examination is correctly quoted in reference to the effect of the weight of the keeper and drum-head. The keeper in the model Exhibit 7 is made, as nearly as I can judge, of the proportions indicated in the drawing, and the actual dimensions correspond with those of magnets in common use in telegraphy.

The diaphragm of stout material intended to be indicated is one of thin wood. Taking the specification as a guide, and the dimensions of the parts there particularly referred to, their distances are preserved in the enlargement. The armature, and the electro-magnet and its connections to the diaphragm, are correctly represented. So also the

dimensions of the cones are as near as may be correct, excepting the thickness of the material, which seems to me to be immaterial to the result so far as the function of the cone is concerned, in its use for the mere convergence of sound; and if the thickness or thinness of the cone has any effect upon the result, then to that extent and that extent only is the model of Fig. 7 wanting in correctness. As to the drum-head I have simply followed the directions given in the specification, and have used a "stretched" membrane, such as was and is frequently used for the purpose of covering the openings in apparatus designed to receive and take up vibrations.

My judgment in the selection of this material was perhaps influenced by the use of similar material in the construction of the Reis transmitter, which gave me the best results when covered with a similar membrane.

The stouter material which suggested itself to me was a very thin sounding-board, selected on account of its peculiar adaptability for receiving and transmitting vibrations of varying quickness, a knowledge gained during the past two years from experiments made in relation to telephony. I do not agree with your statement that "the "membrane *a* of the drawing is shown as thick as the armature." It is, perhaps, two-thirds as thick, but, be this as it may, the specification calls for a stretched membrane. I therefore made the drum by securing a membrane over the end of the cone, exercising my own judgment as to the material and method of securing it in place, for which latter operation the specification gives neither drawing nor instructions.

It should be noted here, however, that when trial was made of this device care was taken that the membrane was stretched tightly.

× Q 11. The specification states that the membrane should be "stretched," but the drawing not only shows no means for stretching the membrane, but it exhibits the membrane united to the cone at a line without any visible means for attaching it. Where is your authority for making a groove around the outside edge of the cone and tying the membrane over it by a string, when the usual method for stretching the membrane over the cone in an instrument designed for the very purpose of having the membrane spoken to and caused to vibrate (as, for instance, Scott's phonautograph) is to stretch that membrane by screws so as to obtain and preserve the required tension, as was done in the Centennial membrane telephone which you saw Professor Bell exhibit?

A. The method of attaching the membrane by making a groove around the outside edge of the cone and tying the membrane over it,

is and was a very usual method of attaching a tympanum where the production of no especial musical note is required, and that method is set out in the description of the Reis transmitter, and which device could well be taken as a guide in the absence of other instructions in the specification.

At the time of the issue of the patent of 1876 Scott's phonautograph and instruments requiring exact adjustment of the tympanum were not of common knowledge, and the device which Mr. Bell exhibited at the Centennial did not resemble that of Fig. 7, and, in fact, had a different arrangement of the magnet and armature, as has been already noted in my former answers, so that device of Mr. Bell's could not be taken as a guide for the details of construction of a model of Fig. 7. It must also be remembered that the skilled mechanician who constructed telegraph instruments, to whose occupation the construction of telephonic devices most pertained, especially as the title of the patent calls for improvements in telegraphy, was not skilled in the making of acoustic devices, and had as a precedent the Reis instrument, which was most nearly allied to the device of this patent.

It may then be fairly concluded that if the inventor desired to have a drum-head with adjustable tension, the specification should have set the fact out, the more especially if no device for the purpose was shown in the drawing.

The Bell exhibit at the Centennial which was provided with screws for stretching the membrane was a very different device from that of Fig. 7, as in it the hinged armature "attached to the centre of the "stretched membrane" at one extremity is done away with, and an independent armature is secured to the centre of the adjustable membrane.

× Q 12. I also observe that the cones in Fig. 7 are composed of some material which is represented as thicker than the armatures themselves. Now, when you were making a "Chinese" copy of that drawing, why didn't you carry out those proportions and make the drums firm instead of making them of thin material, if you supposed that the drawing was designed to give specific directions as to dimensions instead of being addressed to persons skilled in the art to construct it according to the knowledge which electricians have about similar subjects?

A. In my answer to cross-question 10, I have referred to the thickness of the material employed for constructing the cone of the model. The dimensions of the cones are practically like those shown in the

drawing, and the thickness does not interfere with their functions as convergers and conveyers of sounds.

The drawing in the patent was put into the hands of a skilled mechanician, who has been familiar with telegraphic and telephonic devices for many years, and who has constructed many pieces of apparatus for experimental and practical use, with directions to construct it of such enlarged dimensions as would make the magnet and keepers of the dimensions usual among telegraphers, I also directing the cones to be made of brass, as the most durable material. I examined particularly the magneto arrangements, and I am satisfied that they correctly represent the device set out in the drawing attached to the patent, and I am also satisfied that the failure to make the cones as thick as the enlargement of the section in the drawing would make them, does not interfere with their specific functions. No directions are given in the patent for the selection of material.

If, therefore, the failure of the device of Fig. 7 to transmit two or more musical tones at one time is due to the want of a proper relationship of the parts, or to the absence of means for adjusting the membrane of the drum-head, the error is due to the lack of instructions in the specification to that effect.

× Q 13. In the drawing of Fig. 7 is it not true that the keeper is magnetically connected with one of the poles of the electro-magnet, whereby it is itself magnetized, in consequence of which the magnetic force between it and the opposite pole or core is strengthened and great efficiency is given to the instrument in consequence, as distinguished from the case where the keeper or armature is connected to the diaphragm alone, and is not therefore magnetized by the current which magnetizes the core of the magnet? I don't ask you to go into any calculation about the amount of increased attraction resulting from this arrangement, but only to say whether or not it is true that such increased attraction does result from that arrangement.

A. It is true that "the keeper is magnetically connected with one "of the poles of the electro-magnet whereby it is itself magnetized," and the attraction between the other pole and keeper is increased. The attraction is greater than where the keeper, presented unmagnetized to the single pole of the magnet, is connected to the diaphragm only. Increased attractive power results from this specific arrangement by which the poles of different nature are approximated, instead of the attraction only of one pole for a soft-iron armature.

× Q 14. Did you believe, when you had that model made and en-

larged from the drawing Fig. 7, that it was the instruction of the patent that a telephone constructed according to it must be a Chinese copy of that drawing, and when enlarged must be so enlarged as to remove the armature out of the reach of the delicate undulations in strength of current which the vibrations of the diaphragm under the force of the air-waves would produce?

A. The model was made in good faith, and until it was tested by trial did not present itself to my mind as a device that would not operate to some degree. I must first premise that it did not seem to me to be adapted for use as a telephone in the now ordinary sense which that word is used, *i. e.*, a transmitter of articulate speech, nor is there any hint to that effect in the specification.

It is coupled in the description in the patent with another device which was designed as an improvement in telegraphy, by which several signals could be sent over the same closed circuit in a telegraph wire at one time.

For this reason I looked upon it as a second device for transmitting sounds telegraphically, and avoiding as far as possible any reference to my knowledge of the methods of transmitting the articulate messages referred to in the patent of 1877.

In exercising my judgment as to the method of enlarging the drawing so as to make an instrument of dimensions suitable for practical work, I endeavored to exercise that amount of knowledge which was likely to be possessed by a competent maker of telegraphic apparatus at that time. And as I have before said, the novelty of the application of a continuous current by which the keepers of the magnets were never allowed full sway, did not include the necessity for that closeness of approximation which is necessary with the use of a circuit which is constantly being broken and made electrically.

In fact, it would be necessary to modify the relative positions of the parts to effect such a change as would allow the close approximation of the magnet and armature in the usual way. What I mean to say is, that the angle at which the suspended armature is shown in the drawing, forbids the proper approximation of the plane surface of the armature and pole of the magnet in parallel or nearly parallel planes.

To do this, either the stud which secures the end of the armature to the drum-head must be shortened, and the magnet moved up towards it by shortening the leg *d*, or else the leg *d* must be shortened and a new point of suspension made so as to bring the armature nearly or quite plumb and close to the end of the pole of the magnet. With a

battery of three cells the armature is now approached very closely to the lower edge of the core, but this does not by any means give the sort of approximation that is usual in ordinary telegraph relay magnets.

To give the desired approximation in the right way would require the changes in design referred to above.

Taking the above facts in connection with the matter set out and specifically claimed in the patent of 1877, a method of constructing the apparatus so that the magnet and armature can be adjusted in their relative positions, and the fact stated that "the distance of "the magnet from the plate should be as little as possible," I am satisfied that my judgment in relation to the enlargement of the model is correct, and that the inventor was not then impressed with the necessity for approximation which he announces and provides for by a specific device described and claimed in the subsequent patent of 1877.

× Q 15. Then if you had chosen to make it twice as large as you did you would have thought, as a person skilled in the art of telegraphy, which you say this machine was designed to work in, that you ought to remove the armature again twice as far as you have already done in this model in order to carry out the intention of the inventor as expressed in the specification?

A. The matter of degree of enlargement selected can hardly be termed broadly a choice, as a definite reason was assigned for the adoption of the scale upon which the enlargement was based, to wit, the probable use by the inventor of such material as was used in ordinary telegraph work.

I took the smallest magnet in office use that I was familiar with and made that the standard for dimensions, assuming that in the absence of explanation or specific directions, the inventor intended to use ordinary material. This scale made the instrument of such moderate dimension that it could be readily manipulated. If I had selected a larger size of magnet as being the sort that the inventor would have likely used, then it would have been proper to enlarge the model in all of its parts to that degree, but such a choice would not have made the instrument nearly twice so large.

× Q 16. In your examination-in-chief you have stated that the magneto telephone, not using any battery but with the permanent magnet according to the Bell second patent, was not a practically operative apparatus, and you state that, "the extreme feebleness of the results "obtained in this way of working without any aid from the voltaic

"battery current has prevented the useful application of the devices "for the ordinary purposes for which it is desirable to transmit articu- "late speech." Where did you derive the information which enabled you to make that statement of fact?

A. From my own experience in the use of the magneto telephones I found that I could not use them practically for ordinary communication at moderate distances. Early in the year 1878 I purchased a number of hand phones for the purposes of experiment in transmitting articulate speech and musical sounds. These instruments I found to be difficult of use, and so feeble as to necessitate careful exclusion of all outside sound; in fact, they gave me less satisfactory results than the string or wire telephone with metal discs, commonly called the Lover's telephone, which works without a battery or magnet current. I had quite a number of the magneto telephones constructed, having permanent magnets built up from a larger number (over fifty) of small bars strongly magnetized; these instruments gave better results; at that time I determined that the feebleness of action of the electro-magneto telephones as thus constructed was partly due to the inability of the diaphragms to take up sounds, except within a limited compass, and I had constructed various magneto telephones with diaphragms of greatly differing dimensions, for the purpose of transmitting music having a wide range of tones; although I succeeded in taking up and transmitting tones of every pitch combined, the extreme feebleness of the transmission prevented any practical application of the apparatus.

Again, the transmissions of voice were so "small" and feeble, that insignificant imperfection in hearing prevented the listener from receiving the communication.

I am not aware of the continued use for any purpose of the magneto telephones as transmitters, but do know of their large use as receivers in combination with a transmitter, that is, they are used by sending through them a strong electric current of many times the force of the magneto current generated by induction produced by the motions of the plate before the electro-magnet.

It is upon these facts that my opinion as to the feebleness of the current in the magneto instruments is based.

× Q 17. Having derived your information from your own experiments, you will be astonished to know that right here in the city of Philadelphia a telephone exchange was in operation for a long time before the microphone transmitters were in use, using nothing but the magneto transmitters and receiver without batteries; that both the Bell Company and the Western Union Company had telephone ex-

changes in many places in the United States using nothing but the magneto telephone without batteries; that the great suit of the Bell Company *vs.* Dowd, an agent of the Western Union, was to restrain the Western Union Company from the use of such magneto instruments in its regular business, and that there were many thousands of those instruments in daily common use for business purposes during the years 1877 and 1878, and afterwards; that during the year 1877 public exhibitions were made of these magneto instruments talking between Boston and New York, Boston and Providence, New York and Philadelphia, published numerously in the newspapers of that day; and that to-day a pair of those magnetos are better articulators than any microphone transmitters in use.

[*Objected to by defendants' counsel as assuming the existence, as facts, of matters and things not in evidence.*]

A. My first use of this kind of telephone was early in the year 1878, and I was aware of the communication of concert sounds from New York to Philadelphia, but I was not aware of the general use of these instruments without a battery current in exchanges. I have no knowledge of the present use of these instruments in exchanges; but only know of the extensive use of microphone transmitters, and therefore concluded that they had displaced the older sorts. Taking the statement set out in the question for fact, the statement made by me as to the prevention of the useful application of the devices for the ordinary purposes, by reason of the extreme feebleness of the results obtained by the use of the magneto telephone, is evidently an error, and I desire the correction to be made as from want of information in relation to such use.

× Q 18. In your direct examination, I understand the argument as set forth, is this:—

First.—An induction coil, such as is used with the telephone, will not develop a current from the secondary unless the battery circuit is broken on the primary, which you have found by experiment.

Second.—The microphone transmitter of the defendants does generate a current from the secondary coil.

Third.—Therefore the microphone in that instrument is a circuit breaker.

Is not that the position you take?

A. Yes, sir; the results of the experimental determination and conclusion are correctly stated.

× Q 19. Is the magneto transmitter of Fig. 7 a circuit breaker?

A. No, sir.

× Q 20. And you distinguish between Fig. 7 and the defendants' transmitter in this respect by saying that one is and one is not a circuit breaker?

A. Yes, sir.

× Q 21. Then if an induction coil is put into connection with the magneto transmitter of Fg. 7, and a secondary current is taken off to a receiver, the instrument will not talk, as you understand it, because the circuit is not broken on the primary of the induction coil?

Adjourned to meet Wednesday, April 15, 1885, at 11 o'clock A. M.

WEDNESDAY, April 15, 1885.

Met pursuant to adjournment at 11 o'clock A. M.

Present: Same counsel as before.

The cross-examination of Dr. Charles M. Cresson is resumed:—

A. In my answers concerning the action of the induction coil I have referred only to the use of a battery current alone, and have not until to-day experimented with the magneto induced current in conjunction with a battery current through the primary of an induction coil, such a combination of current not being suggested in any of the devices shown nor mentioned in the patents for that purpose. When Fig. 7 is connected through the primary coil of an induction coil with a battery in the circuit, and a Bell telephone receiver is connected in the secondary circuit, and the keeper of the magnet of No. 7 is disturbed, there is an evident disturbance of the current, in the secondary coil, indicated in the receiver. In this case, then, it is evident that a current has been generated in the secondary by the superposition, or rather the changes of tension, caused in the battery current by the magneto current, without a break in the primary circuit.

If this experiment in any way represents the action that takes place between the electrodes of a loose contact transmitter, then my conclusions are wrong; but as no such combination of battery and induced magneto current is suggested in any of the devices, for use with an induction coil, nor in fact is an induction coil an element of any of the devices described or shown, I made no trial by this method until noon to-day, at your suggestion, and find the results to

be as above stated. My determination of the behavior of the current in the secondary coil was by a method set out in the patent of 1876, as one of those suitable for producing the desired and described undulatory current.

× Q 22. If you are mistaken in assuming that circuit breaking of the battery current on the primary is a necessary condition for the operation of the induction coil of the defendants' apparatus, you will admit that the fact that the defendants' apparatus does talk, does not prove nor tend to prove, that a microphone is a circuit breaker?

A. If my premises are wrong the conclusion which I have arrived is wrong also.

My method of experiment was as follows: I made trials of induction coils of various dimensions, the largest giving ordinarily with a five-cell battery an induced spark of about one inch in length. The resistance of the secondary coil eighteen hundred ohms.

When the circuit upon the primary was broken, a spark passed between the points of two wires which were secured about one-sixteenth of an inch apart in the secondary circuit.

A battery in which the plates could be raised out of, and lowered into, the liquid in the cells, was connected through the primary coil, and the plates gradually raised and lowered, sometimes slowly, and at other times rapidly, so as to expose a varying surface to the action of the liquid.

At no time did a spark pass the break in the secondary coil. To further test the matter a Bell telephone receiver was inserted in the secondary circuit, but it gave no evidence of disturbance except when the plates were accidentally raised entirely out of the liquid. This was one of the methods set out in the patent for producing an undulatory current, the one most readily made use of. From this result I concluded that the undulatory current was insufficient to produce a current in the secondary circuit, as such a current only appeared when the current in the primary coil was broken. This method of operation seemed to me to produce a current which corresponded with the undulatory current described in the specification.

If my premises are wrong then the conclusion based upon them will be incorrect.

× Q 23. Don't you understand from the patent that the undulations which are to be generated by Fig. 7 are electrical undulations similar in form to the vibrations of the air accompanying the said vocal or other sounds, as the patent states it?

A. It is true that the patent so states; but the patent also

states in illustration that "undulations are caused in a continuous "voltaic current" by several other methods, and among them by "the "vertical vibrations of the elements of a battery in the liquid in which "they are immersed," "by alternately increasing and diminishing the "power of the battery."

This method occurred to me to be one by which the current described as "undulatory" could be produced, having the authority of the patent as to its suitability for the purpose.

Two other forms of current are described as characteristically different from the undulatory current; and I was not aware of any method by which the pulsatory current could be distinguished from the undulatory in its various degrees of correspondence, I therefore took that certain method of producing the undulatory current which had the sanction of the patentee. To have taken the electrical vibrations produced by the action of the air upon a diaphragm would not have afforded me a basis for determining to which class that form of vibration belonged. The synthetical method of examination seemed to me to be the most appropriate.

× Q 24. You don't mean to say, I presume, that the various *forms* of undulatory current described in the patent (one of which is by vibrating tuned reeds) are the particular *forms* of undulations specified in the patent, by the general description, that these undulations are "similar in form to the vibrations of the air accompanying "the said vocal or other sounds;" or that the patentee meant to say that an undulatory current capable of transmitting vocal sounds could be produced otherwise than by causing electrical undulations similar in form to the vibrations of the air accompanying such vocal sounds?

A. It is stated in the patent that the "invention consists in the em-"ployment of a vibratory or undulatory current of electricity, in con-"tradistinction to a merely intermittent or pulsatory current;" and the distinction that is pointed out as characteristic between an undulatory and pulsatory is, that in the former the changes of intensity are gradual and exactly analogous to the changes in the density of air occasioned by simple pendulous vibrations, whilst in the pulsatory the changes of intensity are instantaneous.

I understand the distinction to be that in the electrical waves the current is to be gradually increased and then gradually decreased in intensity, and that in illustration of this the current produced by manipulating a battery is given.

As the behavior of an induction coil as to the production of currents in the secondary coil is governed by the treatment of the current

in the primary, it was necessary to determine what the action of the coil was under the peculiar current set out and claimed. It was then proper to select a method of producing the current for experiment, that suggested by the patentee.

My understanding, then, is that such a current as that produced by the varying volume of the battery does actually represent the one which Mr. Bell has secured in his patent, excepting only that the vibrations are slower (of less rate per second) than those produced by the air.

If the battery plates could be immersed at the rate of thirty-two times a second, we should produce exactly the current which would be caused by the vibrations of the diaphragm by a musical note produced by that number of vibrations in a second. There is this difference, however, that the undulatory current requires a gradual, that is, an equable movement of the plates. On the other hand, a current that would be produced by a circuit breaker which breaks and makes the current instantaneously should be an intermittent current.

It is stated on good authority that the current produced in the secondary coil of an induction coil arrives rapidly at a maximum of intensity and then decreases slowly, and that the current of opening is both formed and completed in a time shorter than that of the current of closing, and that the time required to attain a maximum of the current of closing the circuit is nearly twice as long as that of opening, and that the maximum intensity of the current of opening is about three and one-half times that of the current closing.

Data from which these statements are taken are found in a treatise on Electricity and Magnetism, by J. E. H. Gordon, N. Y., Appleton & Co,, 1880, volume 1, and pp. 315, 316, 317. If these facts be true, it would appear that the electrical wave which is produced by the action of an induction coil was governed by other laws than those which govern sound, and that although the air impulse may be the inciting cause, the form of electrical wave would lose its exact correspondence to the waves of air which indirectly cause its formation, and it cannot therefore be represented by the same graphic curve.

This apparent want of correspondence may be an explanation of that which to me is very apparent, that the undulations of air produced by the receiver are not similar to, but resemble, those which accompany vocal sounds; that is, they are not identical with them.

× Q 25. Won't you answer the simple question without going into a discussion about induction coils? Don't you understand the patent to mean that the currents which are to be used for transmitting vocal

sounds are to be not only undulatory in the broad sense of that term, but are to be made to resemble in their undulations the air vibrations which accompany such vocal sounds?

A. I understand it to be the statement set out in the patent; that is, the electrical currents which carry the impressions from the transmitter to the receiver are to resemble in their form of undulation the form of the waves of sound which generate them.

× Q 26. When you tried that little experiment of lowering and raising the battery plates in the liquid of the battery, for the purpose of ascertaining whether currents of electricity effected by the air vibrations of sound-waves would make an induction coil operate, did you suppose for one moment that the undulatory currents you were transmitting were similar in form to the vibrations of the air accompanying vocal sounds?

(The witness states that he is physically unable to proceed any further to-day.)

Adjourned to meet Thursday, April 16, 1885, at 11 o'clock A. M.

THURSDAY, April 16, 1885.

Met pursuant to adjournment, at 11 o'clock A. M.

Present: Same counsel as before.

The witness, Dr. Charles M. Cresson, on account of ill health is unable to attend to-day.

The counsel for complainant produce a telegram from the American Bell Telephone Company at Boston in these words: "About "sixteen thousand Bell magnets telephones in use before battery "transmitters adopted. No data as to Western Union Exchanges "worked solely with Bell magnets telephones. Boston, Chicago, Cin-"cinnati, Philadelphia, St. Louis, San Francisco, Albany, Detroit, "Lowell, New Haven, Waterbury, Bridgeport certainly, possibly "Middletown, Conn.; Oakland, California; Portland, Oregon; New-"port, R. I.; Williamsport, Pa.; Baltimore, New Orleans, Washing-"ton, Nashville, Louisville, and Columbus, Ohio."

And another from W. C. Tompkins at Boston in these words: "There is in operation in Boston to-day an exchange of five hundred

"subscribers for express service only equipped with Bell magneto "telephones, without microphones. Each subscriber has one mag- "neto telephone which is used alternately as transmitter and re- "ceiver" and he offers to send for a competent witness to prove the truth of these statements. Counsel for respondents admits that such a witness could be produced and would so swear, and therefore waives the production of the witness.

Counsel for defendant offers in evidence the English Letters Patent of Cromwell Fleetwood Varley, of London, England, for Improvement in Telegraphing, No. 78,495, dated June 2d, 1868.

Also English Letters Patent of said Varley for Electric Telegraphs, No. 1044, dated April 8th, 1870.

Said patents are contained in the Dolbear Record, from page 631 to 639, and may be referred to by counsel and printed as therein.

Counsel for complainant offers in evidence the General Report of the Judges of Centennial Exhibition of Group XXV, pp. 20 and 21.

Also Report on Awards Centennial Exhibition, pp. 130 and 131. (Pp. 93 to 97, Dolbear Record.)

Also the newspaper publications in 1876 and 1877 in the same record, between pages 87 and 166.

[*Counsel for defendants object to the newspaper publications for irrelevancy and incompetency.*]

The following was received by the Examiner after adjournment from the witness, Dr. Charles M. Cresson:—

A. Yes, sir; and for the following reasons:—

First.—Because the patent sets out that method as one which will produce undulatory vibrations.

Second.—Because vocal sounds are produced by vibrations of varying frequency, with this difference, however, that the vibrations which I produced were at a slower rate per second than would produce audible sounds.

I cannot perceive what difference of result other than rate of pulse will be produced by dipping the plates twice in a second, or twenty times in a second. If these pulses will produce an audible sound, as a musical note, by causing them to dip fourteen to sixteen times in a second of time, it will be by means of similar pulses from those formed at the rate of twice in a second, that is, they will differ in no respect other than that of the rate of production, and the ability by the increased rate of vibration per second to make audible sounds.

I conclude, then, if there be any similarity between the form of electrical current and the air vibrations due to the use of undulatory currents as set out in the patent, the particular form which I produced would correspond to the air-vibrations necessary to make such musical notes as can be produced by the same number of interrupted impulses. As every vocal sound consists of musical notes of definite pitch, or rather of combinations of them, the ability to produce

pulses capable of reproducing one by such a method as we have been considering, includes the ability to produce any other one of them by simply adapting the rate of movement to the rate of vibration required.

× Q 27. In your direct examination you say "articulate speech is "not a continuous sound, but is a succession of sounds, entirely sepa- "rated from each other by greater or lesser intervals; so that each "articulation, forming part of a syllable or separate articulate sound, "endures a definite time." You also say that when you tried the defendants' telephone, "when conversation was carried on through the "instruments and connecting wire, a succession of short disconnected "currents passed through the wire, and when the syllables or phonetic "sounds were slowly enunciated, the impression of each group of im- "pulses was very evident." Now does it not appear to you to be true that this observation demonstrated that the electric current was in unison with the sound-waves of articulate speech as you have correctly defined it, and that, in the language of the patent, the electrical undulations might be "represented graphically by similar curves"?

A. The demonstration referred to shows:—

First.—That the communication was made through a wire, which did not constitute a closed circuit, with a single main battery upon it, which combination is set out in the patent of 1876 as one of the advantages derived "from the use of an undulatory current in place of a merely "intermittent one," and which is specifically referred to in the claims. The patent of 1877 sets out the same arrangement of battery and circuit wire, and adds also that the desired transmission may be made "without the necessity of using a voltaic battery." This patent, however, refers to specific devices differing from those set out in the patent of 1876.

Second.—The groups of impulses referred to I do not take to be undulations but groups of minute interrupted currents, each of which produces tones of pitch which represent the pulses of air as they expend their force upon and set in motion the receiving sounding-board or diaphragm. After observing the results obtained by the experiment with the dipping battery, and the effects of oft-repeated minute pulsation upon sounding-boards as a means of producing volume of sound, I think that the passage of the current can only be graphically represented by groups of dots—some closer together than others—as a result of the vibrations necessary to create a note high in the scale of pitch, and others more widely separated, to indicate those necessary to create the lower notes, all repre-

senting the minute parts of an interrupted current. Impulses transmitted in this way seem to me to be of the sort proper to produce in a sounding-board the rapid and rapidly changing vibrations which are necessary to develop the air-waves adapted to reproduce articulate speech.

× Q 28. Since yesterday have you not heard articulate speech transmitted through a pair of Bell magneto telephones one of which was in the circuit of the primary wire of an induction coil, and a battery, and the other of which was in the secondary of the same induction coil without a battery?

A. Yes, sir; you made the experiment in my presence to-day. I could hear disturbance in the telephone which was connected in the secondary circuit of the induction coil. The closeness of the two telephones made it difficult to say whether they were articulate sounds, as the sound of speech conveyed through the air likewise was excluded imperfectly from the ear not occupied by the telephone. The disturbance, however, is evidence to me of the independent character of the magneto current induced by the telephone which was in the battery circuit.

× Q 29. In the defendant's machine there is a contact between two electrodes, one of which is of carbon and the other of metal; these electrodes are forced together by the gravity of the induction coil acting as a weight; its inertia acting as an anvil tends to prevent them from parting; they are further pressed together by a magnetic attraction, which varies with the strength of current and which therefore tends to maintain contact all the more when the strength of current increases; the vibration of the diaphragm when spoken to, varies the pressure between the electrodes (or if you prefer to say so breaks the current there), which variation (or rupture if you think so) is in unison with the variations of force in the air-waves excited by the voice; the battery current passing through this carbon joint is itself varied in strength in substantial unison with the varying conductivity at the joint, and being so varied, passes through the primary of the induction coil, in consequence of which the secondary effect, whatever it is, ensues; the diaphragm at the receiving station vibrates in unison with the transmitting diaphragm in consequence of the effect produced upon its magnet by the secondary current; and in consequence of such vibration the air in contact with it is set into vibrations, whose forms agree with the forms of vibration of the air at the transmitting end, and hence speech is transmitted.

Is not that a true statement of the operation whether you assume

the microphone to vary the strength of current by mere variation of pressure, or by minute breaks of contact?

A. The statement as to the theory of the defendant's patent as to the operation of his transmitter as set out in the question is correct; and the method of operation is correctly stated, except so far as relates to the action of the electrodes upon the current in the battery circuit by varying pressure, no reference being made to the form of the pulses of the transmitting current.

The vibratory movements of the air at the receiving end resemble those at the transmitting end, and hence speech is transmitted.

× Q 30. Is there any difference in the operation of the defendant's transmitter, from the transmitter used in the Spencer case, the Dolbear case, the Hopkins transmitter in the Gregan case in New Jersey, and the Baxter transmitter in the Overland cases, in consequence of which you would say that the Clay transmitter, when in operation, works upon a method substantially different from Bell's patented method, while the others work upon a method substantially the same. I show you copies of the Spencer and Dolbear transmitters, and copies of the Hopkins and Baxter patents, and ask you to point out to the court the characteristic in the Clay instrument which distinguishes it from the others.

A. The transmitters of Spencer, Dolbear, and Hopkins which you have shown to me, and that described in the Baxter patent, are each of the loose contact class, and in that respect like the Clay, although the Spencer has the contact secured by the use of springs, and the Dolbear and Hopkins by the action of gravity alone.

In the Baxter one of the electrodes is suspended by a pendulum, and the contact of electrodes is made by the action of gravity and in addition by magnetic attraction. In this respect the Baxter and Clay instruments are similar in general construction and mode of operation. The Dolbear method of securing contact is by the weight of a weighted electrode. So far as the peculiar device of the Clay transmitter is concerned, it most resembles the Baxter, and in its mode of action may be considered to be identical with it.

I do not consider that the behavior of the electrodes in the Spencer, Dolbear, or Hopkins is identical with that of the Clay, for the reason that in the Spencer a spring is used to secure contact of the electrodes, and in the Dolbear and Hopkins gravity alone. In the Baxter and in the Clay the magnetic attraction added to the gravity effect produces a promptness of action which the springs do not afford, and gives another property which the spring does not possess, to wit, an

additional pressure when the electrodes are closely approximated, which is the reverse of the case with the spring.

All of these instruments make use of an induction coil through the primary coil of which the transmitter current passes with a battery in the circuit, and all of them use the secondary wire of the induction coil as the medium of connection with the receiver. In this respect they are precisely like the Clay instrument.

The Clay transmitter can then be said to possess the characteristics of the Baxter in each particular, and in a general way those of the other three transmitters examined.

If it is determined that the other instruments named work upon the same principle, so far as relates to the current produced in the line wire, and are similar to the Bell, then is the Clay also similar.

× Q 31. Do you wish the court to understand that in your opinion similar sounds to those uttered to the transmitter of an electric telephone will be heard to proceed from the receiver, unless the varying strength of the current transmitting those sounds is practically in unison with the variations in the air-waves producing the sounds, or, to use Sir William Thompson's statement of the operation, "The strength of its current must vary continuously, and as nearly "as may be in simple proportion to the velocity of a particle of air en- "gaged in constituting the sound?" (See page 83 of Dolbear Record.)

A. In my opinion sounds similar to those spoken into a transmitter can be reproduced by a current of unvarying strength, although the separate sounds may carry different degrees of loudness.

Without discussing the theory set out by Mr. Bell that articulate speech can be transmitted by means of an undulatory current of electricity, I am decidedly of the opinion that speech can be transmitted by an interrupted current, and that the device of the defendant does actually transmit speech by means of a current which is interrupted and neither continuous nor undulatory.

The recent experiments which I have made (and witnessed as made by you), in which the superposition of an induced magneto current upon a continuous battery current transmitted speech, taken in connection with the fact set out in the authorities, and as I believe confirmed by my own observations, lead me to suppose that the induced current is *practically* one of sudden creation and equally sudden disappearance, and in the experiments referred to, played the part of a separate interrupted current, or at most converted the continuous current into a pulsatory current having the effect of an intermittent one upon the secondary of the induction coil.

The principal objection which *apparently* forbids such a theory is that sounds varying in loudness at the transmitter are transmitted and delivered by the receiver as sounds varying in loudness or intensity.

It is an undoubted fact that all articulate speech is produced by vibrating sounds of varying pitch and usually with varying volume.

Articulate speech produced by the utterance of sounds that are of the same volume or loudness is called (but falsely) " monotonous."

This expression indicates the use of but a single tone or pitch for the utterance, but it is impossible to produce the various vowel and consonant sounds without great variations of tone (or pitch), and therefore such speech is better represented as being spoken of uniform force. Each and every individual tone produced in speaking can be produced by the vibrations of a reed or by successive blows upon a sounding-board.

The difficulty presented in a mechanical contrivance in the production of speech consists chiefly in the generation of the proper tones in proper succession or at the same time as the components of a clang. In the Faber talking machine vibrating reeds produced the desired tones, of which some of the overtones were generated by variations in the form of the cavities through which the reedy tone was conducted or passed out from the machine.

It is evident, therefore, that all of the necessary sounds can be produced by the vibratory movements of reeds or other suitable appliances.

The mechanical requisite in a sounding-board or diaphragm is the ability to take up the great variety of vibrations promptly, and cause the vibratory movements to as suddenly cease when the exciting cause ceases.

I can see no difficulty in transferring the vibrations received by a sounding-board from air to a current which shall receive the individual vibrations as separate and distinct impulses or interruptions. In fact, I cannot see how a solid body like a sounding-board can receive vibrations from the air except as separate shocks caused by the sudden stoppage of the air-vibrations which impinge upon it, and thus by their weight and momentum cause it to take up motion.

The air-vibration required to produce the note corresponding to two hundred and fifty-six vibrations per second moves at the rate of eleven hundred and eighteen feet per second, and is nearly four and one-third feet across. Now this wave is suddenly stopped by striking the diaphragm or sounding-board, which it moves but a very small fraction of an inch. It must not be forgotten that the velocity of sound

through the air is always at the same rate (to wit, eleven hundred and eighteen feet in a second of time), no matter what the pitch of the sound may be (either high or low); and no matter what the loudness may be, loud sounds set a greater volume of air in vibration.

When air imparts its percussive movement to other bodies, it does so by its momentum, and this explains the cause of some sounds being louder than others.

The greater *surface* or area of a sounding-board set in motion, the louder will be the sound. The sounding-board is a resisting body and the air strikes it, and gives up its motion to the board. A note produced by vibrations of two hundred and fifty-six times in a second, means that the air is beaten by some body capable of setting it in motion at that rate; its momentum will be the weight of air multiplied by its velocity. A note produced by vibrations at the rate of one hundred and twenty-eight times a second, is caused by waves twice as far across the crests as are the waves of the one vibrating at the rate of two hundred and fifty-six times a second, but the one vibrating at the half-rate contains twice the weight of air, and hence they have equal momentum.

The same note which is communicated by air-waves can be reproduced by tapping the sounding-board or diaphragm with a light hammer at an equal rate of speed.

Every sound is communicated by vibratory movements which travel at different rates of speed, in different media, (as in light gases, air, wood, water, metals), but they travel always at the same rate of speed in the same medium.

The communication of sound through other media than air is by means of interrupted vibrations, just as are those produced by the tuning-fork, and the hammer on the sounding-board.

It may be inquired, then, how is it that variations in the loudness of sound can be communicated by intermittent vibrations.

The method by which this is effected is similar to Faraday's method of exhibiting the effect of the inductive action of magnets by means of the galvanometer.

That is by a repetition of small impulses. He says in his Experimental Researches on Electricity, London, 1855, volume III., p. 335 :—

"The vibration of the needle was slow, and it was easy, therefore, "to reiterate the action five or six times or oftener, breaking and mak- "ing contact with the galvanometer at right intervals, *so as to combine* "*the effect of like induced currents*, and then a deflection of 10° or 15° "on either side of zero could be readily obtained."

This same method of repetition, by which time is given to set a greater number of particles in vibration, will produce a loud sound from a body which from a single impulse, or a few impulses, will yield but a moderately loud sound.

In illustration of this I will instance the ordinary Chinese gong, which with one or two taps gives a comparatively small response, but with repeated light blows will produce a "roar" of sound.

In this case the air vibrations which produce the sound are themselves produced by percussive blows such as could be caused by intermittent currents of electricity, representing the receiving end of a telephone worked in that manner. The converse of this, that is, the production of the blows upon the plate by means of air-waves, would represent the receiving end of the telephone.

To me it seems most probable that with bodies like metallic plates and bars the louder sounds in telephonic apparatus are only produced by a prolongation of the times during which they are subjected to the impulse. When we consider how many vibrations per second are necessary to produce even the *lowest* notes of the voice in speaking, say sixty-four vibrations in a second, the difference of time between the production and effect of one and of four such vibrations will not be perceptible to the ear, whilst the mechanical effect of the greater number is probably more than four times that of the least number.

It is undoubtedly true that the number of tones (range of pitches) receivable by any given diaphragm is limited. That is, the ordinary magneto telephone receiver will not take up very low or very high tones; and this I have satisfactorily demonstrated by the use of telephones with diaphragms of various dimensions, constructed for the purpose of taking up vibrations from all parts of the ordinary musical scale.

The fundamental tones which could be produced most readily by the vibrations of the plates employed, are most readily taken up, and others with difficulty in degree as they depart from that fundamental pitch.

I can see nothing, therefore, to prevent the transmission of articulate speech by interrupted impulses, when the bodies to which the sound-waves and electric impulses are applied are adapted to receive vibrations greatly varying in number and changing in number at short intervals.

It is to this cause I consider that the transmission of articulate speech is effected in such instruments as use loose contacts and usually with one electrode of *hard* carbon.

The hard carbon does not in my hand give evidence of additional conductivity when subjected to the moderate pressure which is received in the defendant's transmitter, and I can see no good reason why contact of the electrodes should not be broken at such small intervals of time as will adapt the device to the production of a proper intermittent current for the conveyance of articulate speech.

In further explanation, all air-waves are formed by alternate condensations and rarefactions, and it is the impingement of the condensed portion (crest of the wave) which marks the time of vibration and of greatest pressure against the body struck by the wave.

The waves formed upon the surface of water serve as an illustration of the effects of air-waves by considering the depth of the wave at its crest as representing the degree of compression of the air-wave.

The reason why we cannot directly compare the behavior of water and air-waves in every particular, is that air is compressible and can be packed into a smaller compass or space by pressure, whilst water is incompressible, and when a force is exerted upon it in one place, the surface level is disturbed by the rising of the water into a hill or wave to balance the pressure.

The height of this wave indicates by its hydrostatic pressure the amount of force necessary to produce it, and when a force parallel to the surface of the water is applied, the indication of force is the elevation of a wave at right angles to the line of force.

In the compression of air, the chief direction of condensation is in the line of the force causing it, and from these differences in the behavior of air and water arises the popular difficulty in understanding graphic illustrations of sound-waves.

Every sounding body has weight and consequently inertia, and it requires time as well as force to set it in motion; and it will yield but a given distance to an impulse of given weight. A single impulse exerted for a fraction of time will not push the surface of a sounding body to the distance which it would go by the exertion of a continued pressure of the equal amount; but repeated impulses will in time effect that which a few impulses of equal force fail to do. When the maximum movement in a diaphragm which a given force will produce has been effected, further impulses fail to produce a louder sound, but merely maintain the maximum of effect.

A diaphragm, in receiving vibrations from the air, swings to and fro; that is, it is pushed a certain distance and then returns to its original position, and, by its momentum, swings in the direction opposite to that to which it was moved by the first pressure against it.

The ability to promptly recover its position is one of the essentials of a sounding-board, and this to and fro motion is termed pendulous.

An air impulse does not swing to and fro in the pendulous manner of the sounding-board, but it progresses in one direction, each succeeding vibration following its predecessor in regular file (if the tone is maintained of one pitch), and in closer or more distant companionship as the vibrations are generated more rapidly or more slowly.

The successive impulses which are to reproduce the sound impulses in the air by means of a diaphragm at the receiving end must then be generated by the motions of the transmitting diaphragm in the same distinct, separate, processional, and variously grouped manner as are the *crests* of the waves of air which impinge upon the receiving sounding-board or diaphragm.

FRIDAY, April 17, 1885.

Met pursuant to adjournment, at 11 o'clock A. M.

Present: Same counsel as before.

The cross-examination of Dr. Charles M. Cresson is resumed:—

× Q 32. Don't you understand the impulses spoken of in your answer to cross-question 27 to be such as are represented in the diagrams page 126 of complainant's case, in which the syllables of the words "Brown's University," "How do you do?" each appears disconnected from the next syllable by an interval of no air-vibration, or of very insignificant vibration?

A. I understand the group of impulses which is referred to, to represent the crests of the waves, such as appear at the upper part of the curves shown in the drawing to which you refer, and in which I find eighteen in number as these exist in the word "Brown." My opinion is that each of these crests represents the maximum of pressure upon the sounding-board, and as such indicates the end of a movement of that board from that impulse. The next movement of the board is to return towards the position which it occupied before the impact of that impulse, and it is prepared to receive the next impulse.

To me it seems that these separate crests represent so many taps, as it were, upon the sounding-board, and that the collection of them (as shown, for instance, in "Brown") represents a group of minute interrupted currents, such as I referred to in answer to cross-question 27. The line between "Brown" and "University" represents the space of time which I refer to as giving evidence of no current.

× Q 33. And if the electric current is similar in form to this group of air-vibrations, then it will excite in the receiving magnet a series of impulses similar to the transmitting air-wave, and so transmit speech, whether you describe that group of air-waves as broken and separate or as air-undulations?

A. Certainly. If the electric current is put into that state of action by impulses which correspond to the periods of greater condensation of the air-wave, it will similarly excite the receiving magnet, and transmit speech, and this whether the impulses received from the air are broken or separate or as an undulation.

× Q 34. As you understand it, is articulate speech transmitted in the Bell magneto telephone by "a current of unvarying strength," or by means of the sort of current specified in the patent?

A. In the transmission of articulate speech by the Bell telephone, in which magneto currents are alone used, I believe that the impulses which are derived by induction are suddenly created, and of short duration, and generated at each movement of the diaphragm. I base this opinion upon the statements in the authorities (one of which is Gordon upon Electricity and Magnetism, as to the duration and character of induced currents I have particularly referred to recently), and also upon my own observations.

These currents, then, would be figured as successive groups of minute impulses, each representing impulses, each representing some tone or group of tones produced by and necessary to reproduce articulate speech.

Subject to the variations in time of creation, attainment of maximum, and duration, as given by Gordon, pp. 316 and 317, they may be considered practically to be portions of an interrupted current of unvarying strength, as the differences in effect between them could not be perceived by the ear.

× Q 36. And, entertaining that view of the Bell magneto telephone, do you say that the defendant's telephone substantially differs from it, in respect to the character of the currents generated by its use, for the purpose of transmitting vocal or other sounds?

A. No, sir. In my opinion the same character of current, to wit, one which consists of groups of minute intermittent currents, separated more or less by greater spaces, is used by both.

The differences between the two devices being in the method of operation by which the intermittences are produced and by which they are transferred to the receiving apparatus.

× Q 36. As you understand the Reis instrument, as described by

its inventor and in the various publications in scientific journals before 1876, is it not described as constructed for the purpose, and as producing the effect, of breaking the electric current at each complete air-vibration, and thereby alternately magnetizing and demagnetizing some form of electro-magnet at the receiving end as many times as there are air-waves per second in the transmitted sound?

A. Yes, sir. The description is that of an instrument designed for transmitting vibrations by means of an interrupted current of electricity.

× Q 37. Don't you understand that the metallic diaphragm in the 1877 patent and exhibited in Figs. 2 and 3 in section, is one designed to vibrate like a stretched membrane being supported around its edges?

A. So far as mere substitution of an iron plate for the stretched membrane as a medium for the reception of impulses from air is concerned, there is no difference between them.

But as regards the method of operation as a means of transferring the vibrations there is a difference. The iron plate will receive in close succession vibrations of greatly varying rate, which the membrane will not do.

The stiff iron plate requires a positive force to set it in vibration, and practically ceases to vibrate when the impulses cease.

In consequence of this the iron plate held fast at the edges will readily receive the various rapid changes of tone and clang which are produced by the human voice, whilst the action of a membrane is so limited in that respect that very little more than vowel sound can be taken up by it.

× Q 38. In your testimony did you mean to say that the combination with an electro-magnet of that sort of plate of iron or steel, for the purpose of a telephone, was to be found in any of the relays or in the Reis No. 2, which is substantially a Morse relay?

A. So far as the mere combination of an iron or steel plate with an electro-magnet is concerned the ordinary relays and the Reis receiver No. 2 (the Legat receiver) are constructed in the same manner as is the subject of the third claim of the 1877 patent, but the relays were not used for telephonic purposes; and the Reis receiver No. 2, although used for telephonic purposes, did not reproduce articulate speech.

In neither instance was the plate in the form of a diaphragm secured at its edges.

× Q 39. In the sounding-box, Fig. 2, a narrow air space between the diaphragm and the speaking-tube is shown. Did you mean to say

that in the Reis or any other apparatus referred to by you there was to be found a sounding-box of similar construction to that?

A. In the Reis instrument the diaphragm is set in one side of a cubical box, into another side of which box is inserted a speaking-tube.

The air in the box serves as an elastic cushion, and tempers the violence of concussion which would result if the air vibrations were narrowly directed upon the membrane or diaphragm.

In the device of Fig. 2 the tube is directly opposite to the diaphragm, the stiffness and weight of the iron plate acting in conjunction with the air space to prevent the effect of strong concussions. To this extent the sounding-box of Reis performs the same functions as the narrow space in the sounding-box of Fig. 2.

Both boxes form a part of the channel leading from the mouth of the person talking to the diaphragm which is to receive the air impressions.

It is true that the Reis box is not of the exact form of that of Fig. 2, nor is the air space similarly proportioned, but so far as the cushion of the vibrations is concerned they each perform it in different degrees of effect.

× Q 40. Did you mean to say that a stretched membrane with an armature fast to it, as in the Centennial instruments, differed from the thin metallic diaphragm in the circumstance that one includes a "vi- "bration damper" as you call it, to cause the vibration to cease, and the other does not? and if so, will you explain why, when both diaphragms are drawn powerfully by magnetized armatures, and vibrated freely by feeble changes in magnetism, they will not both cease to vibrate under the permanent pull of the magnet in the same time after the vibratory impulse has ceased?

A. When I made answer to my direct examination, I did not consider the effect of a membranous diaphragm with an armature secured to it without other connection like the Centennial instrument. No such device is shown in the patent of 1876.

The membrane of Fig. 7 was rigidly connected to the keeper of the magnet and by the keeper to a fixed point. This method of construction compelled the diaphragm to carry with it the parts mentioned, and as a consequence of their great momentum prevent the rapid taking up of motion, and prolonged the time of its action.

The diaphragm having a light keeper secured to it without other attachment was similarly affected, but to a much less degree.

The chief difference between the diaphragm with the light keeper secured to it and the light metallic diaphragm results from the inhe-

rent stiffness of the metallic diaphragm, which causes its rapid and exact return to a normal position when released from the influences which caused its movement.

The membrane has no such inherent power, and the straining process to which it is subjected is but an imperfect substitute for the natural stiffness of the iron.

It is this want of ability to resist movement that enables the diaphragm to receive delicate impressions; the same quality also prevents the sudden cessation of the movements, and takes away the power to receive rapid vibrations of varying speed at short intervals.

Adjourned to meet Saturday, April 18, 1885, at 11 o'clock A. M.

SATURDAY, April 18, 1885.

Met pursuant to adjournment, at 11 o'clock A. M.

Present: Same counsel as before.

Defendant's counsel offers in evidence English Letters Patent to Peter Jensen for Improvements in transmitting and printing telegraphic messages, and an apparatus therefor, dated September 2, 1874, No. 2999, and the same is marked "Defendant's Exhibit, Jensen Patent."

Also Letters Patent of United States to Elisha Gray, for Improvement in Electric Telegraphs for transmitting musical tones, dated July 27, 1875, No. 166,095, and the same is marked "Defendant's Exhibit, Gray's Patent A."

Also Letters Patent of United States to Elisha Gray for Improvement in Electric Telegraphs for transmitting musical notes; dated July 27, 1875, No. 166,096, and the same is marked "Defendant's Exhibit, Gray's Patent B."

Also models of Figs. 5 and 6 of Bell's patent of 1876, four in number, marked respectively "Defendant's 5 and 6 A, B, C, D."

The cross-examination of Dr. Charles M. Cresson is resumed:—

× Q 41. Are not the screw nuts on these models, which are copies from the patent drawing, for the purpose of bringing the vibration armature close up to the magnetic coil, so as to obtain the effect of the undulatory current?

A. Yes, sir; and they are necessary to enable the use of a constant battery of a given power.

If the strength of the battery is modified from time to time, the adjustment of the tongue can be adapted to the strength of the bat-

tery so as to secure the maximum of vibratory power in the spring. That is, the stronger the battery the further the tongue can just be set from the core of the magnet, as, the stronger the battery, the greater will be the amplitude of the motion in the spring.

× Q 42. And do not the same conditions exactly exist in this respect in Fig. 7 as in Fig. 5 ?

A. The same conditions exist, but in Fig. 7 there is no provision made for any such adjustment.

× Q 43. Is it not true that in all the electro-magneto machines, which these Figs. 5, 6, and 7 are, and well known to be so for the last forty years, the further and more rapidly the armature was moved to and from the magnet, the stronger would be the current generated in the coil ?

A. The magneto current is generated by the movement of the keeper in relation to the magnet. The times of generation of the current are at the commencement and at the end of the motion, which changes the relation of the magnet and armature. To secure an apparently continuous current from these separate impulses velocity of movement is necessary. The greater induction effect is produced by keeping the magnet and keeper closely together with rapidly repeated small movements of approach and recession.

With the spring device of Exhibit 5 and 6 a difficulty interposes, which prevents the spring from being set in close adjustment, and yet permits of its use for variations in battery power.

The flexibility of the spring permits it to touch the coil of the magnet when closely adjusted, if used with a strong battery; and when it touches the core it remains in contact, and the vibrations are prevented.

When a strong battery is used the spring is to be raised, and set at a greater distance from the core, thereby losing the stronger inductive effect of motion close to the core of the magnet. I do not, therefore, agree with that part of the proposition in the question which refers to the benefit to be derived from great motion in the armature. A good illustration of the effect of distance in decreasing the induction of magneto effect, is found in the adjustment of the plate of the Bell receiver, in the patent of 1877, and of which the patentee says, "it is "important that the distance of the magnet from the plate should be "as little as possible, without however being in contact."

This statement is found in the 1877 patent, and is not referred to in that of 1876, which described the Exhibits 5, 6, and 7.

× Q 44. Then, if I understand you, the well-known law of the mag-

neto machine is that the closer together the armature and magnet are, the greater the inductive effect will be when the armature is vibrated?

A. Yes, sir.

Affirmed and subscribed before me, this eighteenth day of April, A. D. 1885.

SAMUEL BELL,
Examiner.

} CHARLES M. CRESSON, M. D.

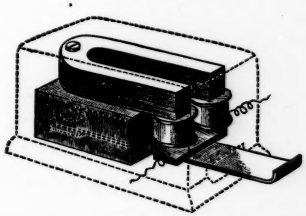
Defendant's counsel also offers in evidence model of Hughes relay, marked "Defendant's Exhibit, Hughes Relay."

Also an ordinary Morse relay, marked "Defendant's Exhibit, Morse "Relay."

Also article entitled "An Application of Magneto-Electricity," by Sir Charles Wheatstone, contained in *The Telegraphic Journal* and *Electrical Review*, volume 1, pp. 4 and 5, London, November 15, 1872. The portion of which is as follows:—

"* * * So far back as 1840 Sir C. Wheatstone invented an instru-"ment for this purpose, founded on the principles of his electro-magnetic "step-by-step telegraph, when voltaic electricity was applied thereto. "But batteries involve troublesome chemical operations, and if not con-"stantly attended to their inactivity causes the failure of the entire sys-"tem. Voltaic batteries are subject to many accidents, through which a "temporary irregularity in the registration may ensue; they may be sit-"uated in so cold a place that in winter the exciting liquid is frozen or "the vases cracked; or they may be exposed to the heat radiated from

FIG. 1.



"hot air or water-pipes or other source of warmth, and the liquid "evaporated to crystallization, the crystals forming a non-conducting "coat upon the electrodes of the pile. But, given success with the "battery, the rapidly succeeding contacts render constant inspection "necessary. The spark that appears on breaking contact is nothing

"less than a minute particle of the metal of the contact-point in a state "of incandescence, and it follows that where the current passes and "is interrupted many times must speedily be worn away. This "difficulty was subsequently overcome by the inventor employing "magneto-electric currents, and the following is a description of a "suitable apparatus for the generation of these currents in which the "circuit is never broken.

"On reference to Fig. 1 it will be seen that the essentials of the ap- "paratus are a small permanent magnet, two coils of fine wire with "soft-iron cores, and an armature of soft iron. The spring to which "the armature is attached presses the armature against the soft-iron "cores of the bobbins, maintaining the strength of the magnet when "the apparatus is not in use. When, by pressure on the lever, the "armature is quickly removed from the poles of the magnet, a current "is induced in the coils of wire, and is communicated by leading wires "to the register, or indicator, Fig. 2, where it acts by means of an "electro-magnet upon a step-by-step motion precisely similar to the "motion imparted to the needle of the receiving instrument of the "A B C telegraph. On the return of the armature into contact with "the soft-iron prolongations of the permanent magnet, a current is "generated in an opposite direction to the first.

"The first current caused the hand of the indicator to advance hal "the distance between two of the figures upon the dial; the second "current completes the movement, and records one action of the ma- "chine to which the apparatus may be attached." * * * *

Adjourned to meet Monday, April 20, 1885, at 12 o'clock noon, at office of Charles Howson, Esq., No. 119 South Fourth street.

MONDAY, April 20, 1885.

Met pursuant to adjournment, at 12 o'clock M., at the office of Charles Howson, Esq., No. 119 South Fourth street.

Present: FURMAN SHEPPARD, ESQ., *Counsel for Respondents;*
CHARLES HOWSON, ESQ., *of Counsel for Complainants.*

MR. SHEPPARD, counsel for defendants, rests.

MR. HOWSON, of counsel for complainants, says:—

That in order to enable the case to be argued at this term of the court, complainants consent to go to hearing without offering evidence in reply, reserving, however, the right to put in further proofs in case for any reason the cause shall be continued or go over to a later term of the court.

PUBLICATIONS BY REIS AND OTHERS RELATING TO THE REIS TELEPHONE.

No. 5. REPORT OF REIS LECTURE.

FRANKFURTER CONVERSATIONSBLATT, Nov. 29th, 1861.

Reproduction des Schalles durch den galvanischen strom (*Frankfurt*).

"*Reproduction of sound by the galvanic current*" (*Frankfort*).

For this new discovery, which rightly excites the greatest interest, we have to thank Mr. Reis, teacher in Friedrichsdorf. He has succeeded after many experiments in solving, up to a certain point at least, this problem, which up to the present has been considered insolvable.

Of all the new discoveries in natural science there are none of so general advantage and which so enter into our practical life as those in the domain of chemistry and physics; in the latter galvanism in its application to electro-plating and telegraphy has achieved remarkable results. At the moment when telegraphy has attained a place in our social life, there begins, perhaps, for the same a new era in the fact that as we in telegraphy make ourselves understood by means of signs, in this we can make ourselves understood by means of tones at a distance.

Mr. Reis has constructed in a very ingenious manner an apparatus by means of which he has shown some perfectly successful experiments before a large audience in the physical society in this city.

He has made a very happy use of the earlier discovery that the iron core of a wire helix produces tones by the interruptions of the current following each other at very short periods.

His apparatus for receiving the sound is based upon the arrangement of the human ear. It consists in the first place of a funnel-shaped cavity [to represent the cartilage of the ear] to receive the sound, closed at its narrower part by a membrane, upon which is fastened an elastic strip of platinum which is connected with one of the circuit wires, while the former is in electric connection with the other pole of the battery.

As soon, then, as the sound-waves set the membrane in vibration, the elastic strip of metal fastened to the same will make the same

vibrations, will alternately rise and fall, thereby touching the other elastic strip and so making and breaking the current.

The reproduction of the sound by the galvanic current, for it is only such and not a conduction of the sound, is brought about in the manner specified above. Into a wire helix, included in the circuit, is placed a thin metal rod—*e. g.*, a knitting-needle—which apparatus, in order to increase the tone, is placed upon an easily vibrating support, a resonant box. By means of the current now made, now broken, the iron rod is also set into vibrations, which are communicated to our ear and there reproduce the sound.

The vibrations of the iron rod correspond with those of the membrane; but as the pitch of the tones is dependent upon the times of vibration of the sounding body, the lower tones escape our notice, while the higher ones are especially noticed.

Up to the present the reproduction of the tones is indeed weak, and words cannot be reproduced. We leave here the question as to whether this hereafter will be successfully accomplished.

Mr. Pritz, instrument maker, has just constructed a new instrument with some improvements, and Professor Boettger will hereafter make experiments with it in the physical society, to which we shall at times call attention.

No. 6. REIS LECTURE.

JAHRES-BERICHT DES PHYSIKALISCHEN VEREINS ZU FRANKFURT AM MAIN; FUR DAS RECHNUNGS JAHR, 1860–1861.

Yearly Report of the Physical Society at Frankfort-a-M., 1860–1861, pp. 57–64 (published in 1862).

"*On telephony by means of the galvanic current, by Philipp Reis.*"

The extraordinary results in the field of telegraphy have probably often raised the question, If it might not be possible to transmit musical tones themselves [Tonsprache] to a distance? Experiments made in this direction could not, however, produce any result at all satisfactory, because the vibrations of conducting media soon lose their intensity to such an extent that they are no longer appreciable by our senses.

A reproduction of tones [Tonen] at certain distances by means of a galvanic current has probably been thought of, but the practical solution of this problem has certainly seemed the most doubtful to

the very persons who, from their knowledge and appliances, were in the best condition to attack it. To a person having only a superficial knowledge of physics the problem presents far less difficulties, simply because the most of them are unperceived. About nine years ago I also (having an extraordinary enthusiasm for what was new, and an insufficient knowledge of physics) had the boldness to attempt the solution, but was soon forced to desist because the very first experiment convinced me of the impossibility of its solution.

Later, after further study and experience, I came to see that my first experiment had been a very rough and by no means conclusive one; I did not, however, follow up the subject seriously, because I did not feel myself equal to the difficulties in the way.

Youthful impressions, however, are strong, and therefore not easily effaced. I could never get rid of the thought of that first experiment and its occasion, notwithstanding all that reason says to the contrary, and thus, half unwillingly, this project of my youth was reviewed in hours of leisure; the difficulties and the means for overcoming them were weighed; but for the present, at least, no experiment was made.

How indeed could a single instrument reproduce the combined effect of all the organs occupied in human speech? This was always the cardinal question; finally I got the notion of putting the question in another way:—

How is *our ear* affected by the totality of vibrations produced by the organs of speech all simultaneously active? Or more generally,

How are we affected by the vibrations of several simultaneously sounding bodies?

To answer this question, we must, in the first place, understand what must happen in order that we may perceive a single tone.

Without our ear, any tone is nothing else than a recurrent condensation and rarefaction of some body repeated at least seven or eight times in a second. If this occurs in the same medium in which we are, the membrane of the ear is at each condensation forced towards the middle ear, to be moved at the subsequent rarefaction in the opposite direction. These vibrations produce a synchronous raising and falling of the hammer upon the anvil (according to other authorities, an approach or receding of the ear-bone particles), and a similar number of tremors in the fluid of the cochlea, in which the filaments of the auditory nerve are distributed. The greater the condensation of the conducting medium at any given moment, the greater is the amplitude of vibration of the membrane and hammer,

and consequently the more powerful the blow upon the anvil and the vibration of the nerves by means of the fluid.

The office of our organs of hearing is, therefore, to transmit with certainty up to the auditory nerve every condensation and rarefaction occurring in the surrounding medium. But the office of the auditory nerve is to bring to our consciousness the vibrations of matter which have occurred in a given time, both as regards number and amplitude. Here, for the first time, certain combinations receive a name; here, certain vibrations are *tones* or *noises* [*Töne* oder *misstöne*].

What our auditory nerve perceives is, then, simply the effect of a force coming within the range of consciousness, and this force can be represented both as to duration and magnitude graphically by a curve.

Let *a b* represent any given time, and the curve above the line condensation (+), the curve below the line rarefaction (—), then any ordinate raised from the end of any abscissa will represent the degree of condensation, at the time represented by its base, in consequence of which the drum of the ear vibrates.

Our ear can under no circumstance appreciate more than can be represented by these curves, and this indeed is entirely sufficient to give us a clear perception of any tone [ton] or any combination of tones.

If several tones [tonen] are produced at the same time, the conducting medium is subjected to the influence of several simultaneous forces, the two following laws will hold good: If the forces act in the same direction, the amplitude is proportional to the sum of the forces; if the forces act in opposite directions, the amplitudes are proportional to the difference of the opposing forces.

If, for example, in the case of three tones, we draw the curve of condensation of each separately, then by a summation of the ordinates of corresponding abscissas, we can determine new ordinates and develop a new curve, which might be called the combination curve. This represents exactly what our ear perceives of the three simultaneous tones. The fact that the musician can distinguish the three tones need not surprise us any more than the fact that any one acquainted with the theory of colors can in green discover blue and

yellow; but the combination curves in Plate I. show that this difficulty is a slight one, for in these curves all the relations of the components successively recur. In the case of chords of more than three notes the relations are not so readily seen from the drawing, Plate II., for example. In the case of such chords, however, the skilled musician also finds difficulty in recognizing the separate notes.

Plate III. illustrates discord [Dissonanz]. Why discords impress us unpleasantly I will leave my readers to judge at this time, though I may perhaps return to the subject subsequently in another paper.

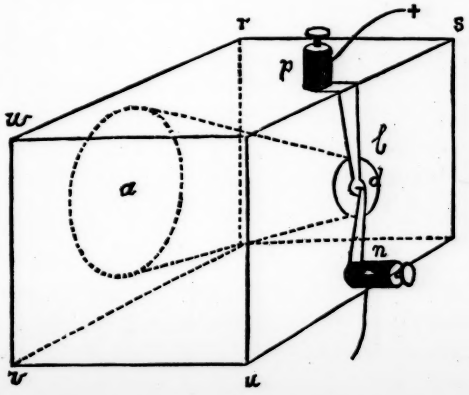
From the preceding it follows:—

First.—Every tone [Ton] and every combination of tones, on striking our ear, causes vibrations of the drum of the ear, the succession of which may be represented by a curve.

Second.—The succession of these vibrations alone gives us a conception (sensation) of the tone, and every alteration changes the conception (sensation).

As soon, then, as it is possible to produce, anywhere and in any manner, vibrations whose curves shall be the same as those of any given tone or combination of tones, we shall receive the same impression as that tone or combination of tones would have produced on us.

With the above principles as a foundation, I have succeeded in constructing an apparatus with which I am enabled to reproduce the tones of various instruments, and even to a certain extent the human voice. It is very simple, and by means of the figure will be easily understood from the following explanation:—



In the cubical block of wood *r s t u v w x* there is a conical perforation *a*, closed at one end by a membrane *b* (pig's intestine), upon the middle of which there is cemented a conducting strip of platinum; this is connected with the binding screw *p* [auf deren mitte ein stromleitendes Streichen Platin feftgelittet ist. Dieses steht mit der klenme *p* in Verbindung]. From the binding screw *n*, another thin strip of metal [ein dunnes metallstreischen] extends until over the middle of the membrane, and ends here in a platinum wire placed at right angles to its length and surface.

From the binding screw *p*, a conducting wire runs through the battery to the distant station, being connected with a coil of silk-covered copper wire, and this again is connected with a conductor leading back to the binding screw *n*.

The coil at the distant station is about six inches long, is composed of six layers of fine wire, and, as a core in its centre, has a knitting-needle which projects about two inches at both ends. By means of the projecting ends, the coil rests upon two bridges of a resonant case. (All this part can of course be replaced by any other apparatus by means of which the well-known "galvanic tones" can be produced.)

If now tones or combinations of tones are produced in the neighborhood of the block, so that sufficiently powerful waves enter the opening *a*, then these sounds cause the membrane *b* to vibrate. At the first condensation the hammer-like wire *d* is pushed back; at the rarefaction it cannot follow the retreating membrane, and the current traversing the strip remains broken [Strom bleibt so lange unterbrochen bis, &c.], until the membrane forced by a new condensation again presses the strip (proceeding from *p*) against *d*. In this way each sound wave causes a breaking and closing [ein Oeffnen und ein Schliessen] of the current [Stromes].

At each closing [Schliessen] of the circuit [kette] the atoms of the iron wire inside the distant spiral are moved away from each other (Pouillet Müller, page 304, Vol. II., fifth edition); on breaking the circuit [beim unterbrechen des Stromes] these atoms seek to regain their position of equilibrium. When this happens, in consequence of the reciprocal actions of elasticity and inertia, a number of vibrations are produced, and they give the longitudinal sound of the rod (see as above). This is the case of the making and breaking of the current [Unterbrechungen und Schliessungen des Stromes] occur with comparative slowness. If they occur more rapidly than the oscillations of the iron core, due to its elasticity, the atoms cannot complete

their course. The paths described become shorter in proportion as the interruptions are more frequent, but then are just as numerous as these.

The iron wire no longer gives its longitudinal (normal) tone, but a tone whose pitch corresponds to the number of interruptions [Unterbrechungen] (in a given time); this is the same as saying that *the rod reproduces the tone* [ton] *impressed upon the interrupter* [dem Unterbrechungs apparat]. The intensity also of this tone is proportional to that of the original one, for in proportion as this is more intense the motions of the membrane are greater; the motions of the hammer, also, and finally the time during which the circuit remains opened, is greater, and consequently up to a certain limit, the motions of the atoms in the reproducing wire are greater, we perceiving them as greater vibrations, in just the same way as we would have perceived the original sound wave.

As the length of the conducting wire can undoubtedly be made as great as in direct telegraphy, I have called my instrument "tele-"phone."

Now, in reference to the capabilities of the telephone, it may be stated that I was enabled to render audible to the members of a large assembly (The Physical Society at Frankford-a-M.), melodies which were sung not very loud into the apparatus in another house three hundred feet away, with closed doors.

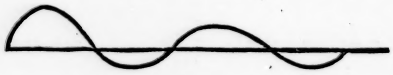
Other experiments showed that the sounding wire was capable of reproducing complete chords of three tones of a piano, upon which the telephone was placed, and that it reproduces equally well the tones of other instruments, accordion, clarinet, horn, organ pipes, &c., provided that the tones are within the compass F—$\overline{f}$.

Of course, in all experiments, sufficient precautions were taken to insure that there was no direct conduction of sound. This is very easily done by making a momentary short circuit immediately in front of the coil, by which means its action is temporarily interrupted.

Hitherto it has not been possible to reproduce the tones of human speech [Tonsprache des Menschen] with a distinctness sufficient for every one. The consonants are for the most part reproduced pretty distinctly, but the vowels as yet not in an equal degree. The cause of this I will attempt to explain.

According to the experiments of Willis, Helmholtz, and others, vowel tones can be produced artificially, if the vibrations of one body are from time to time augmented by those of another, somewhat as follows:—

An elastic spring is set in vibration by the blow of a tooth on a toothed wheel; the first vibration is the greatest, and each subsequent one is smaller than the preceeding.



If, after a few vibrations of this kind (the spring not coming to rest in the mean time), the tooth wheel imparts a new stroke, the following vibration will be again a maximum, and so on.

The pitch of the tone produced in this way depends upon the number of vibrations in a given time, but the character of the tone upon the number of swellings [Anschwellungen] in the same time. Two vowels having the same pitch would differ in about the way represented by the curves (Figs. 1, 2), while the same tone without any vowel character would be represented by the curve (Fig. 3).

Fig. 1.

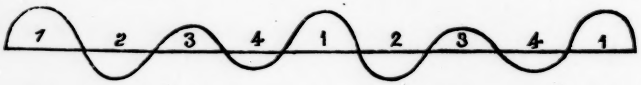


Fig. 2.

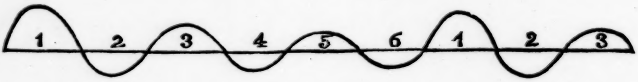


Fig. 3.

Our organs of speech probably produce the vowels in the same manner, through the combined action of the upper and lower vocal cords, or of these latter and the cavity of the mouth.

My apparatus reproduces the number of vibrations, but with an intensity much less than that of the original ones; though, as I have reason to believe, to a certain degree proportional among themselves. But in the case of these generally small vibrations, the difference between large and small vibrations is more difficult to preceive than in the case of the original waves, and the vowel is therefore more or less indistinct.

Whether or not my views as to the curves corresponding to sound combinations are correct could perhaps be decided by means of the new phonautograph of Duhamel (" Vierordt Physiology," page 254).

It may be that for the practical application of the telephone much

remains to be done; for physics it has already sufficient interest, from the fact that it opens a new field for research. *Friedrichsdorf, near Frankford-a-M., December, 1861.*

No. 7. REIS EXHIBITION OF 1861.

FORTSCHRITTE DER PHYSIK, XVII., FOR 1861, pp. 171–3.

PH. REIS. *Telephony by means of the electric current.* (*Annual Report of the Physical Society of Frankford on the Main, 1860–1, pp. 57–64.*)

By the name "Telephone" the author designates the following apparatus of his own construction by means of which and with the help of the galvanic current he is enabled "to reproduce at a distance the tones [Tonen] of different instruments and even to a certain degree the human voice."

A wooden cube is bored through from one of the faces to the opposite one, the cavity taking the shape of a cone; the smaller opening is closed by means of a membrane (hog's intestine, Schweinsdünndarm). On the middle of the membrane and parallel with it is a thin strip of platinum cemented fast at one end whilst the other end is held by a binding post [klemme] *p*. From another binding post *q* extends a similar thin strip of metal as far as over the centre of the membrane, and carries a little platinum wire directed towards the membrane at right angles to the strip and the surface of the membrane. From binding post *p* a conductor leads through a battery to a distant coil, which again is connected by another wire to binding post *q*.

The coil at the distant station is about six inches long, consists of six layers of thin wire, and encloses as a core a knitting-needle which protrudes about two inches at each end. By these protruding ends the coil is supported on two bridges of a sound-board. If now tones or combinations of tones are produced in the vicinity of the large opening of the conical cavity so that sufficiently strong waves enter it, these waves will set the membrane into vibration; by the outward motion of the membrane the platinum strip cemented on it is pressed against the hammer-shaped wire *d* and the galvanic current [strom] is closed [geschlossen]; by the inward motion of the membrane the current is reopened. The alternate magnetizings and demagnetizings of the

core of the coil resulting therefrom will bring forth, if the alternation is slow, the longitudinal tone of the core, and if the alternation [aufeinanderfolge] is quicker, a longitudinal vibration of the same, the period of which corresponds to the period of the interruptions of the current [unterbrechungen des stromes] or of the vibrations of the membrane, and consequently to the rate or pitch of the tone which entered the conical cavity. That means, according to the author, that "The rod "[stab] reproduces the tone which was impressed upon the interrupt- "ing apparatus [unterbrechungs apparat]." "The strength of this "tone is also proportionate to the original tone, for," as the author, though not very accurately, explains, "the stronger this is the greater "the motion of the little hammer, the greater finally the time during "which the circuit remains open, and consequently the greater, up to "a certain limit, the motion of the atoms in the reproducing rod, which "motions affect us as greater vibrations, as the original wave itself "would have done." By means of this telephone the author made audible to the members of a large meeting of the Physical Society in Frankfort-a-M. melodies sung not very loud into the apparatus, in a house situated about 300 feet distant, with closed doors. "Other trials showed that the resounding rod is capable of reproducing "full chords [dreiklänge] of a piano on which the telephone rests, and "that, in short, it reproduces just as well the tones of other instru- "ments, such as the harmonica, clarinet, horn, organ pipe, &c., pro- "vided the tones are within a certain range, from F to f^2 or there- "about.

"As a matter of course, sufficient care was taken to ascertain "whether direct transmission of the sounds had not a share in the "result. This was ascertained very simply by establishing for a "given time a good shunt circuit directly before the coil, in con- "sequence of which, of course, the activity of the latter ceased for that "time.

"It was not possible thus far to reproduce spoken tones [Ton- "sprache des menschen] with a distinctness satisfactory to all; the "consonants are for the most part distinctly reproduced, the vowels "not in the same degree." The author attempts to explain this imperfect reproduction of the vowels by saying that the apparatus reproduces the vibrations to a certain extent indeed with proportionate, but also reduced strength, and the ear can no longer satisfactorily discern the relation of the proportionately great vibrations which determine the pitch [Tonhöhe] to the small vibrations on which vocal quality [vocal Farbe] depends.

No. 8. REIS-LEGAT ARTICLE.

Journal of the German-Austrian Telegraph Association, V. 9, p. 1, 1862.

Concerning the reproduction of sounds by means of galvanic electricity: by V. Legat, Royal Prussian Telegraph Inspector at Cassel, accompanied by copperplates VIII. and IX.

It might not be uninteresting to make known, in wider circles, the following ideas lately communicated by Mr. Philip Reis to the Society of Physics, and to the meetings of the Free German Institute, at Frankfort on the Main, concerning the reproduction of tones [Tonen] by means of galvanic electricity, and, also, what has been hitherto accomplished towards the realization of this project, in order that the accumulated experiments may serve as a foundation to build upon, and that the capacity of the electric current, which by human ingenuity has already been made serviceable for correspondence, may be developed in this direction also.

In this essay we shall not deal with the electric current as to its capacity for operating telegraphic apparatus of whatever construction for the reproduction of *visible* signs, but of the application of this current to the production of *audible* signals, of *tones* [Tonen].

The air waves, which by acting upon the ear excite in us the sensation of sound by primarily setting the typanum of the ear into vibratory motion, are, as is well known, transmitted to the interior parts of the ear and to the auditory nerves there located by means of a lever apparatus of wonderful delicacy, the auditory bones (hammer, anvil, stirrup); and the attempt to reproduce tones therefore depends upon this, to actuate an artificial imitation of this lever apparatus by means of the vibrations of a membrane corresponding to the membrane of the ear drum, and thereby to open and close (zum Oeffnen u. Schliessen) a galvanic circuit, connected with a distant station by a metallic conductor.

Before describing the apparatus to be used, it would be proper to inquire how our ear apprehends the vibrations of any one particular tone, and the combined vibrations of all simultaneous tones acting upon it, because thereby we may determine the operations which are to be performed by the transmitting and receiving apparatus in the solution of the problem.

Examining first the processes which take place in order that the human ear may apprehend any single tone, we find that each tone is the result of alternate rarefactions and condensations repeated within

a fixed time. If this operation occurs in the same medium in which the ear is placed, then at each condensation the membrane is forced toward the cavity of the drum, and toward the opposite side at each rarefaction.

These vibrations cause corresponding movements in the auditory bones, and are thereby transmitted to the auditory nerves.

The greater the degree of condensation of the sound-conducting medium is at a given time, the greater will be the amplitude of vibration of the membrane and auditory bones, and the greater the consequent result; and in the opposite case, so much the weaker. Hence it is evidently the function of the auditory apparatus to impart with faithfulness to the auditory nerves every condensation and rarefaction which occurs in the surrounding medium, On the other hand, the function of transmitting to our consciousness both the number and amplitude of the resulting vibrations occurring within a given time devolves upon the auditory nerves.

It is here, in our consciousness, that a certain complex phenomenon receives a specific name; it is here, in our consciousness, that the transmitted vibrations become tones [Tonen].

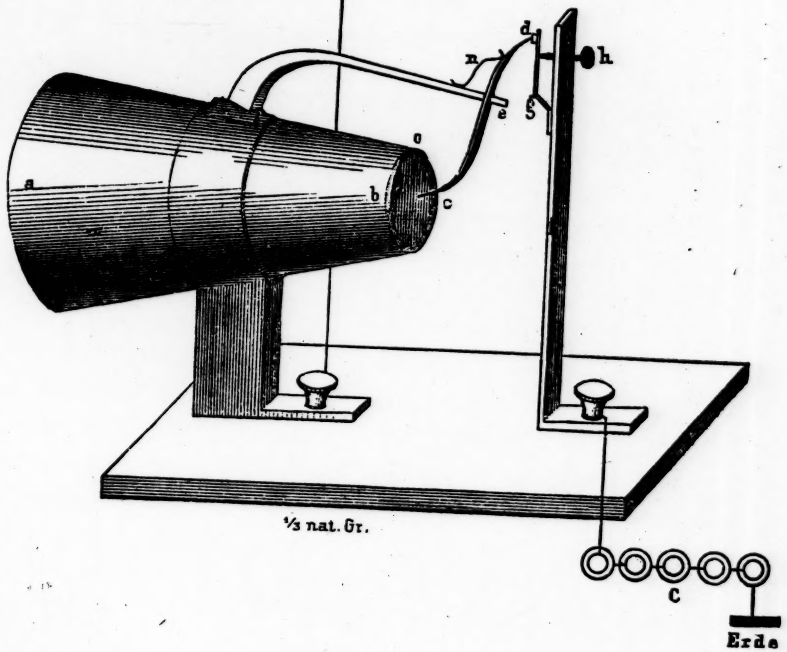
Accordingly, that which is apprehended by the auditory nerves is the effect of a force, reaching to our consciousness, and which can be made more easy of comprehension, as to its duration and strength, by graphical delineation.

For example, let the length of the line *a–b* represent a definite period of time, the curves above this line the condensations (+),

and the curves below this line the rarefactions (—); then every ordinate erected at the end of any abscissa will indicate at the moment of time indicated by this abscissa, the degree of condensation in consequence of which the membrane of the drum vibrates.

The ear is not capable of perceiving more than can be represented in this way, or more than can be represented by similar curves; this is, however, sufficient to convey to our consciousness any single tone [Ton] or any required combinations of tones. For if several tones are generated simultaneously, then the tone-imparting medium is influenced by several forces, acting at the same time, and subject to mechanical laws.

If all the forces act in the same direction, then the amount of motion is in proportion to the sum of all the forces; if on the other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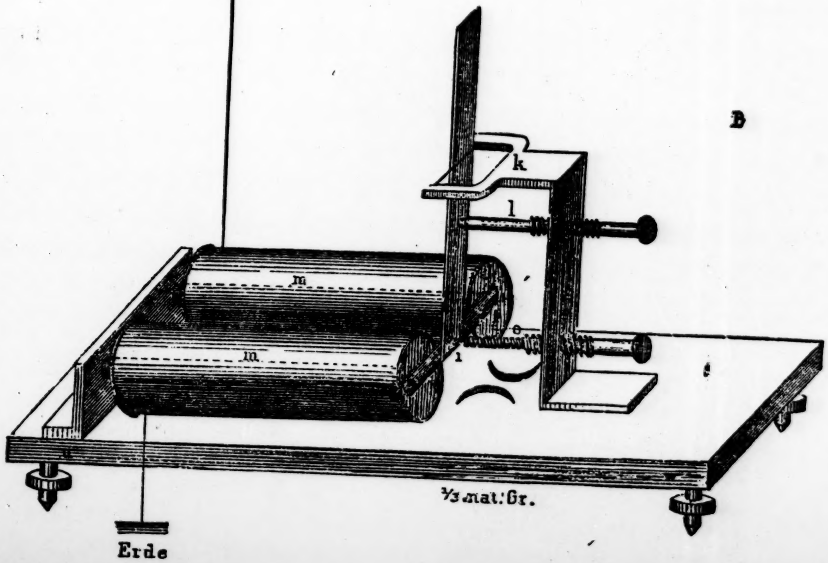
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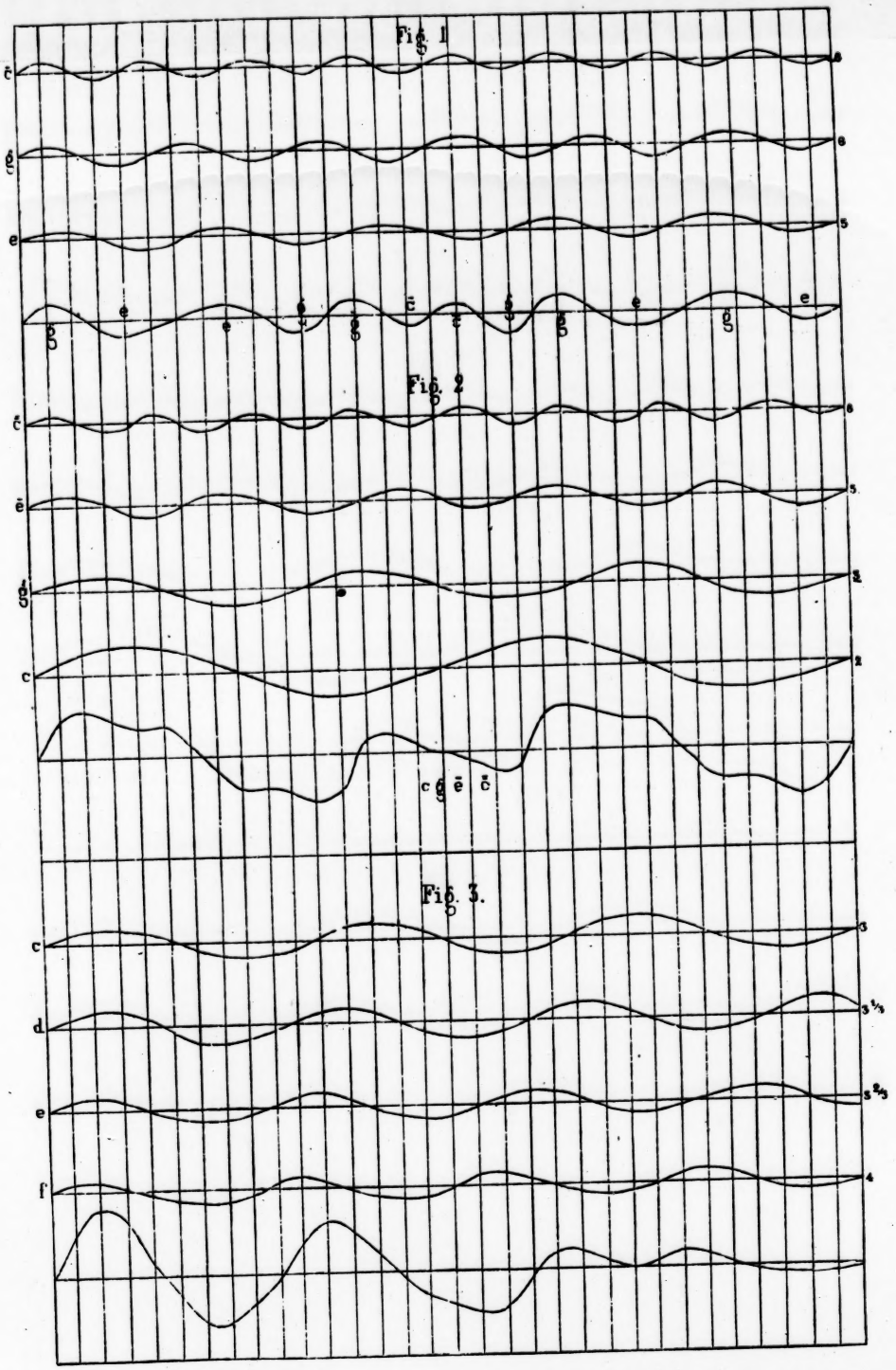


Ernst & Korn Berlin.

hand the forces act in opposing directions, then the amount of motion is in proportion to the difference between the opposing forces.

From these principles it follows that the curves representing the condensations of a number of simultaneously generated tones may be combined in a single curve of condensation, which will indicate with precision what our ear apprehends through the reception of these simultaneously acting tones.

The objection generally made to this proposition, that a musician, or any person, is able to distinguish the simple tones out of which these composite curves are formed or arise, should not be allowed to militate against it; as it is also possible for some who are familiar with the study of colors to distinguish, in green, for example, the mixture of yellow and blue, in their varied shades; and the one phenomenon as well as the other is referable to the fact that each observer is very familiar with the factors of that product which has been conveyed to his consciousness.

By the explanations heretofore given, it is easy to construct the curves representing the condensations of various tones, chords, &c., and a few examples are given by way of illustration:—

Fig. 1, Plate VIII., represents a composite curve formed of three tones, in which all the proportions of the components recur successively.

Fig. 2 represents a similar curve formed of more than three tones; in this case, however, it is no longer possible to represent the proportions so clearly in the drawing, yet an experienced musician will be able to discern them even here, although in practice it might be difficult for him to recognize the separate tones in such a chord.

The advantage of representing the operation of tones upon the human ear after this manner is that it gives the clearest view possible of the course of the process; the representation here given also shows why a discord [dissonanz], Fig. 3, must affect the ear disagreeably.

This apparent digression from the subject under consideration was necessary to demonstrate that as soon as we are able, in any place and in any manner, to reproduce vibrations of such curves and intensities as are equivalent to the curves and intensities of the vibrations of any particular tone, or of any particular combination of tones, we shall have the same impressions as were produced upon us by this original tone, or these original combinations of tones.

The apparatus described hereafter offers the possibility of producing these vibrations in every manner desired; and by the use of gal-

vanic electricity it is possible to evoke, at any distance, vibrations like [gleiche] those which have been so produced, and in this way to reproduce at any place the tones which have been generated at another place.

In Plate IX., Fig. 4 A is the tone transmitter [Tonangeber], and B the tone receiver [Tonenppfanger], and these two instruments are set up at different stations. I must observe at the outset that the arrangement of the instruments for sending backwards and forwards is omitted for greater clearness; and likewise, as the whole thing is not presented as a completed fact, but only to call to the notice of a wider circle what has been already ascertained, the possibility of the working of the apparatus at a distance greater than the limited direct working allows at present is left out of consideration, since these points are easily accomplished by mechanical arrangements and since the most important facts of the phenomena treated are not influenced thereby.

Let us now turn to the tone transmitter, Fig. 4 A. This on the one hand is connected by the metallic conductor with the tone receiver, Fig. 4 B, at a neighboring station; on the other hand it is connected by means of the electric battery C with the earth, or with the metallic return conductor. The tone transmitter, Fig. 4 A, consists of a conical tube *a b*, about 15 centimetres in length, having a front opening of about 10 centimetres, and a rear opening of about 4 centimetres.

It appears by practical experiments that neither the material of this tube nor any increase in its length influenced the accuracy of the action of the apparatus. An enlargement of the diameter of the tube impairs the working of the apparatus, and it is desirable that the inner surface of the tube be as smooth as possible. The smaller or rear end of the tube is closed by a collodion membrane *o*, and upon the centre of the circular surface of this membrane rests one end *c* of the lever *c d*, the supporting point *e* of which is sustained by a bracket, and is kept in electrical connection with the metallic conductor. The proper lengths of the respective arms *c e* and *e d* of this lever are regulated by the laws of the lever. It is advisable to make the arm *c e* longer than the arm *e d*, in order that the least motion at *c* may operate with greatest effect at *d*. It is also desirable that the lever itself be made as light as possible, that it may follow the movements of the membrane. Any inaccuracy in the operation of the lever *c d* in this respect will produce false tones at the receiving station. When in a state of rest the contact at *d g* is closed, and a delicate spring *n* maintains the lever in this position.

The second part of the apparatus, the standard *f*, consists of a metallic support, connected with one pole of the battery C, the other pole of which is connected to the earth, or to a metallic return wire leading to the other station.

Upon the standard *f* is arranged a spring *g*, with a contact-point corresponding to the contact-point *d* of the lever *c d*; the position of *g* is regulated by the screw *h*.

In order not to impair the operation of the apparatus by the action of the air-waves against the rear side of the membrane, it is desirable to place a disc of about fifty centimetres in diameter at right angles to the longitudinal axis of the tube *a b*; this disc may be attached to the tube by a fastening surrounding its outer circumference.

The tone receiver, Fig. 4 B, consists of an electro-magnet *m m*, which rests upon a sounding-board *n w*; its coil is connected respectively with the metallic conductor and the earth or the metallic return conductor.

Facing the electro-magnet *m m* is an armature, to which is attached a very long but light and broad lever *i*.

The lever *i* with the armature is suspended from the standard *k* in the manner of a pendulum, its motion being regulated by means of the screw *l* and the spring *q*.

In order to increase the capacity of the apparatus, the tone receiver may be placed at one of the focal points of an elliptical chamber of suitable size, and the listener may place his ear at the other focus of this chamber.

The operation of the apparatus described is as follows:—

When at rest the galvanic circuit [kette] is closed. When the air, which is in the tube *a b* of the apparatus, Fig. 4 A, is alternately condensed and rarefied, by speaking into it (or by singing or introducing the tones of an instrument), a movement of the membrane closing the smaller opening of the tube is produced, corresponding to such condensation or rarefaction. The lever *c d* follows the movements of the membrane, and opens and closes [öffnet und schliesst] the galvanic circuit [kette] at *d g*, so that at each condensation of the air in the tube the circuit is opened, and at each rarefaction the circuit is closed [ein Oeffnen und ein Schliessen erfolgt].

In consequence of this operation, the electro-magnet of the apparatus, Fig. 4 B, in accordance with the condensations and rarefactions of the column of air in the tube *a b*, Fig. 4 B, is correspondingly demagnetized and magnetized [demagnetisirt und magnetisirt] and the armature of the magnet is set into vibrations like those of the mem-

brane in the transmitting apparatus. But the beam [Balken] *i* attached to the armature communicates these corresponding vibrations of the armature to the air surrounding the apparatus Fig. 4 B, which finally transmits the vibrations so produced to the ear of the listener.

We have not here to consider the question of the transmission [Fortpflanzung] of tones by means of the galvanic current, but only of the conveyance [Uebertragung] of generated sounds to another place, and in this way that at the latter place a similar cause is produced, and a similar effect obtained. It must not be ignored, however, that while the apparatus described reproduces the exact number of the original vibrations, but not of the same strength (die gleiche stärke der reproducirten schwingungen noch nicht erreicht wurde); and that the achievement of this result is reserved for an improvement of the apparatus.

In consequence of the imperfection of the apparatus at this time, the minor differences of the original vibrations are distinguishable with more difficulty—that is, the vowel sounds appear more or less indistinct—inasmuch as each tone depends not merely upon the number of the vibrations of the medium, but also upon its condensation and rarefaction.

This also explains why chords and melodies were transmitted with marvelous accuracy in the practical experiments hitherto made, while single words in reading, speaking, &c., were less distinctly recognizable, although even in these the inflections of the voice, as in interrogation, exclamation, surprise, calling, &c., were clearly reproduced.

There is no doubt that the subject we have been considering, before it becomes practically valuable for use, will require considerable improvement; it will especially be necessary to perfect the mechanism of the apparatus to be employed; but I am convinced, by repeated practical experiments, that it is of the greatest theoretic interest to pursue these investigations, and also that a development of practical value will not elude our intelligent century.

Nos. 9, 10, 11. INDUSTRIAL GAZETTE.

"Deutsche Industrie Zeitung," 1863, Chemnitz.

No. 9, April 17th, 1863, No. 16, page 184:—

"*Industrial queries for exciting interest and eliciting responses.*

"Of late there has been talk in newspapers about producing defi-
"nite tones at a distance, similarly to telegraphic dispatches, such,

" for instance, as conducting the acoustic effects of an instrument far " beyond the reach of the audibility of its sound. Do these com- " munications rest upon actual facts?"

No. 10, May 1st, 1863, No. 18, page 208:—

" Answers. Answer to question in No. 16, page 184. Transmission " of Tones by Electricity. According to the 'Böttger's Notizblatt,' " 1863, No. 6, successful experiments in 'telephony' were made in " October, 1861, at Frankfort-a-M. by Professor Ph. Reis, so that it " seems not impossible to carry on conversations at miles distance, " and even to convey the voice itself with its peculiar undulations, " and also the tones of a musical instrument. Heretofore the voice " could be reproduced from one house to another only for a dis- " tance of 300 feet by means of a peculiar and ingenious appa- " ratus. The arrangement of the same was essentially as follows: " The waves of sound were taken up by an elastic surface, and trans- " mitted to a light commutator introduced into the circuit of a gal- " vanic battery [einer federnden cummutator eingeschaltet in den " Leitungsdraht]. At the other end of the line was introduced a coil " of copper wire, inside of which was an iron wire resting upon a " sounding-board, that was thrown into sonorous vibrations by the " changes of current depending upon the waves of sound."

No. 11, May 29th, 1863, No. 22, page 249.

" *The reproduction of tones by electro-galvanic means (with a drawing,* " *which is the same as the drawing of the apparatus in the Legat arti-* " *cle, No. 8, pp. 539–45 supra).*

" Although this subject has already been discussed by us (No. 18, " page 208), on account of the great interest it offers we shall return " to it more in detail. We enclose a drawing of an apparatus used by " Mr. Ph. Reis, in Frankfort-a-M., taken from the Zeitschrift des " Deutsch-Oestereichschen Telegraphen Vereins, 1862, folios 6, 7, and " 8. We take the liberty of following the lead of the above-mentioned " source in entering into a short discussion of the nature of tones.

" The undulations of the air that excite in us, by operating upon " the ear, the sensation of sound, by setting the drum of the ear into " vibration, are transmitted, as is well known, by a series of levers of " admirable delicacy; that is, by the small bones of the ear (hammer, " anvil, and stirrup) to the inner portion of the ear, and to the nerves " that lie at that point. The attempt to reproduce tones depends

"upon the following: To set in motion an artificial imitation of this "series of levers by the vibration of a membrane which takes the "place of the drum, and to make use of them to open and close a "galvanic circuit which is connected by a metallic conductor with a "remote station.

"If we take into consideration the phenomena that take place when "we perceive a sound by the sense of hearing, we find that every tone "is the result of rarefactions and condensations of the air repeated "several times in a certain period. At every condensation the mem-"brane of the drum is pressed inwards, and at every rarefaction out-"wards. These vibrations produce a simultaneous motion of the "small bones of the ear and a consequent transmission to the nerves "of the ear. The greater the compression of the sound-conducting "medium at any particular moment, the greater is also the ampli-"tude of vibration of the membrane and small bones of the ear, and "*vice versa*. The object, therefore, of the organs of hearing is to "transmit with certainty the rarefactions and condensations of the "sound-conducting medium to the nerves of hearing. On the other "hand, it remains their object to bring to our perception the vibrations "occurring in a given time with reference to number as well as to "amplitude. It is only in our perceptions that a given combination "receives a definite name, that vibrations become sounds.

"Anything other than the effect of such single vibrations the organs "of hearing are unable to take up, and these organs themselves are "competent to perceive single tones as well as combinations of tones, "for if several tones are produced at the same time the sound-con-"ducting medium is under the influence of several simultaneous "forces which according to the laws of mechanics can be replaced by "a force which produces the same effect as all the single ones together. "If all the forces operate in the same direction the magnitude of the "motion is proportional to the sum; if they operate in opposite di-"rections the magnitude of the motion is proportional to the differ-"ence of the opposite forces. In that way several simultaneous tones "operate upon our hearing simply by a definite alternation of rarefac-"tions and condensations of the sound-conducting medium, as in the "case of single tones. The tone itself depends apparently only upon "the number of vibrations and the power upon the amplitude of the "vibrations (perhaps also the strength).

"Now, as regards the apparatus, the upper figure is the transmitter "and the lower one the receiver or reproducer.

"The transmitter consists of a metallic conical pipe *a b*, about 15

"centimetres in length, 10 in diameter at *a* and 4 in diameter at *b*. "At *b* the opening is closed by a membrane *o* of collodion stretched "tight. Upon the centre of the same rests the end *c* of lever *c d*, "whose fulcrum is placed at *e* on a support. The lever is to be made "as light as possible, and its arm *c* longer than its arm *d*, so that the "smallest motion at *c* will operate at *d* with the greatest amount of "force. In the condition of rest the contact *d g* is closed and a weak "spring *n* holds the lever fast in this position of rest. Besides, there "is attached to the apparatus a metallic standard *f*, connected with one "pole of the battery, while the other pole is led to the ground "through *e*. On the standard *f* is secured the spring *j* opposite the "contact-point *d* of lever *c d* at *d*, the position of which (spring) can "be regulated by a screw *h*.

"The receiver consists of an electro-magnet *m m* resting upon a "sounding-board R, and whose coils are in connection with a metallic "conductor and with the earth at E. Opposite the electro-magnet "is an armature connected with a lever, as long as possible, but light "and broad. This lever is fastened to the support *k* after the manner "of a pendulum, and its motions are regulated by a screw *b* and "spring *g*.

"To increase the efficiency of the apparatus the receiver and repro- "ducer can be set up in one focus of an elliptical concavity of proper "size, while the listening ear of the hearer is placed in the other "focus.

"The operation of the apparatus is now as follows: The tones of "the voice or of an instrument are conducted into the conical pipe *a* "*b*. By reason of their vibration the membrane is set into similar "vibration, and in this way operates the opening and closing of the "electric conductor. In consequence of this the magnet in the "receiver will be magnetized and demagnetized corresponding to the "vibration of the tones, and the armature of the lever *i* is set in vi- "brations corresponding to those of membrane *o*. The wide surface "of lever *i* transmits these vibrations to the air, and by this means "they reach the ear of the hearer. In this transmission of tones, the "only question is one of transmission of vibrations, a problem that "magneto-electric telegraphy is certainly sufficiently far advanced to "deal with.

"A friendly communication was sent us some time ago by Mr. J. "F. Quilling of Frankfort-a-M., according to which the capacity of "the apparatus to transmit tones to a considerable distance clearly "and with their characteristic timbre [Klangfarbe] is fully established.

"Mr. Q. writes us that by means of the telegraphic conductor with "which the apparatus of Mr. Ph. Reis was connected, two remote "parts of the city were united, and although it was not possible with "the present construction of the apparatus to transmit spoken words "[gesprochenen Wörte], they succeeded so well with the tones that "were sung that not only were the melodies of songs reproduced dis- "tinctly and perfectly at a tolerably remote station, but known voices "could be recognized. All present capable of judging, Mr. Q. adds, "who availed themselves of the opportunity of witnessing the experi- "ment, agreed that the possibility is before us of making one's self "understood verbally at any distance in the way shown by Mr. Reis."

No. 12. BÖTTGER'S ARTICLE.

Böttger's Polytechnisches Notizblatt, 1863, No. 61. On the Transmission of Tones at any desired Distance, by Means of Electricity. (*Telephony.*)

Two decades ago the problem of giving signs, by means of electricity, from distances had not yet been entirely solved. Since then telegraphy has reached such a perfection and telegraph wires have so greatly spread that even the keenest desires have not much left to ask for.

Now there appears a first earnest trial to reproduce tones at any desired distance, by means of electricity.

This first trial, which has been crowned with success, has been repeated in the lecture room of the Physical Society of Frankfort-on-the-Main, before numerous assembled members, on the 26th of October, 1861, by Mr. Ph. Reis, teacher of natural sciences at Friedrichsdorf, near Frankfort. Into one part of his apparatus, located in a building about three hundred feet distant, and having all the doors and windows closed, melodies were sung, but not very loudly. The same could be heard by the members in the lecture room, through the second part of the apparatus.

These wonderful results were attained with the following very simple apparatus: A small, light box, a kind of hollow wooden cube, has a larger opening in the front, and a smaller one on the opposite side. The latter is covered with a very fine membrane (sausage skin), and the same is tightly stretched; a small, flexible piece or strip of platina, fastened to the wood of the box, touches the membrane at its centre, and a second strip of platina is fastened by one end to the

wood at a different place, and has at its other end a fine horizontal point touching the other strip of platina, where it lies on the membrane.

As is known, tones are produced by the rapid succession of condensations and rarefactions of the air. If the vibrations of the air, called waves, strike the thin membrane, they push the same against the strip of platina that touches it, and then allow it to immediately vibrate back into the hollow cube (called the artificial ear), and so cause the membrane to assume forms alternately bent towards the cube and from the same. The strip of platina lying against the membrane is thus set into a swinging motion, so that it is alternately pressed on to the platinum point of the second strip and then leaves the same.

If one of the strips is connected by a wire to one of the poles of a voltaic battery, and the electricity is conducted to any desired distance by a wire connected to the other pole and is then carried through a helix six inches in length, wound with six layers of thin silk-covered copper wire, and from there is carried back to the second strip of platina on the wooden cube by means of an insulated wire, then, at every vibration of the membrane, an interruption of the current of electricity [Unterbrechungen der Stromung der Electricitat] will be caused, as the point on the one strip of platina no longer touches the other strip. Through the hollow of the spiral a thin iron wire (a thick knitting-needle) about ten inches in length is passed, so that it projects out of each end of the spiral about two inches, and these projecting ends each rest on a bridge of a sounding-board.

It is known that if an electric current is passed through a helix that surrounds an iron wire, at every interruption a tone, produced by the vibrations of the iron wire, is audible. If the makings and breakings of the current [Unterbrechungen des Stromes] follow each other rather slowly, the different positions (in regard to the length of the bar) which the molecules will be caused to assume by the electricity will produce a tone, its so-called proper longitudinal tone, which depends on the length and thickness of the bar or wire.

If the interruptions and reconnections of the current [Unterbrechungen des electrischen Stromes] in the spiral take place faster than the vibrations of the smallest parts of the wire, which in turn depends upon the elasticity of the wire, they cannot complete their course, receive new shocks, the vibrations get to be smaller but more rapid, and as numerous as the interruptions follow each other. The piece of wire no longer gives its longitudinal tone, but a tone which,

according to the number of interruptions in a certain time, is higher if they are more frequent and lower if they are less frequent. It is known that the pitch of a tone depends on the number of air-waves that follow each other in one second. We have seen that the number of interruptions of the electric current [Unterbrechungen des electrischen Stromes] by the membrane and the strips of platina is dependent upon this.

Consequently the iron wire must give a tone of the same pitch as the sound which was received by the membrane. As electricity is hardly impaired when conducted a great distance, if the proper apparatus is used, it is evident that a tone acting on a membrane in one place can be made audible at any desired distance by the iron wire.

That the tone is made audible only by electric vibrations and not by direct transmission of the air-waves through the wires can be most strikingly proved by noticing the fact that no tone is heard at the spiral if a good short circuit be established; *i. e.*, if, for instance, a small strip of metal is laid across the two wires, directly in front of the spiral. The reproduced tones are weaker than the originals, but the number of vibrations is the same. It is easy to reproduce the tones in the proper pitch. As the vibrations are smaller, which is the cause of the weakness of the tone, it is much more difficult, however, for our ear to estimate the difference in the size of the vibrations.

The character of a tone depends upon the number of swellings it has; *i. e.*, with tones of the same depth, consequently of the same number of waves per second, such as having the fourth, sixth, eighth, tenth, or sixteenth wave stronger than the rest.

The physicists have shown that if a spring is vibrated by the teeth of a cog-wheel, the first vibration is the greatest, and every following one is smaller. If, however, before the spring comes to rest, another tooth strikes it, then the next vibration will be equal to the first strongest one, but the vibrations of the spring will not be any more numerous than before. Vowel tones can be artificially produced in this way.

Although we may be far from being able to converse with a friend a hundred miles away and recognize his voice, as though he was sitting alongside of us, the impossibility of attaining this result can no more be claimed.

The probability that this result will be attained is almost as great as, by the wonderful experiments of Niepce, the reproduction of natural colors by photography.

No. 17. REIS'S LETTER TO LADD.

Journal of the Society of Telegraph Engineers and of Electricians for March, 1883, No. 46.

Reis's Telephone.

The following is a copy of an autograph description of Reis's telephone which has been presented to the library by Mr. Wm. Ladd, Member :—

(Copy.)

Institut Garnier,
Friedrichsdorf.

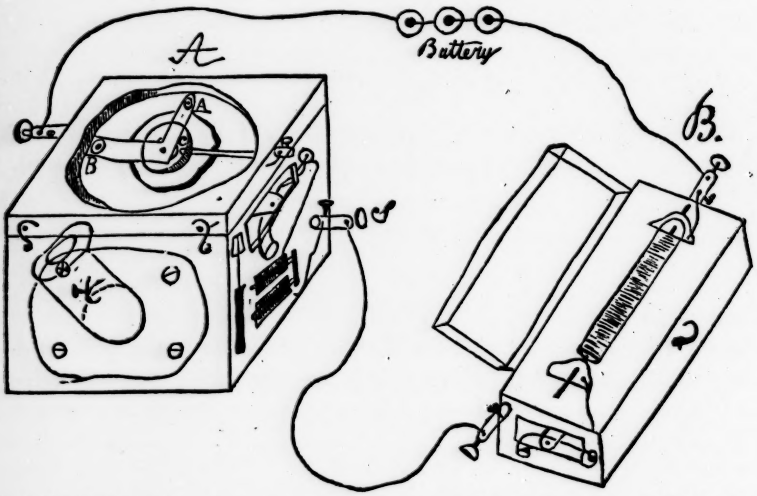
Dear Sir:

I am very sorry not to have been in Francfort when you were there at Mr. Albert's, by whom I have been informed that you have purchased one of my newly-invented instruments (telephons), though I will do all in my power to give you the most ample explanations on the subject. I am sure that personal commuuication would have been preferable, specially as I was told that you will show the apparatus at your next scientifical meeting, and thus introduce the apparatus in your country.

Tunes and sounds of any kind are only brought to our conception by the condensations and rarefactions of air or any other medium in which we may find ourselves. By every condensation the tympanum of our ear is pressed inwards, by every rarefaction it is pressed outward, and thus the tympanum performs oscillations like a pendulum. The smaller or greater number of the oscillations made in a second gives us, by help of the small bones in our ear and the auditory nerve, the idea of a higher or lower tune.

It was no hard labor, either to imagine that any other membrane beside that of our ear could be brought to make similar oscillations, if spanned in a proper manner and if taken in good proportions, or to make use of these oscillations for the interruption of a galvanic current. However, these were the principles which guided me in my invention; they were sufficient to induce me to try the reproduction of tunes at any distance. It would be long to relate all the fruitless attempts I made until I found out the proportions of the instrument and the necessary tension of the membrane. The apparatus you have bought is now what may be found most simple, and works without failing when arranged carefully in the following manner:—

The apparatus consists of two separated parts, one for the singing station, A, and the other for the hearing station, B



REIS'S TELEPHONIC APPARATUS.—FACSIMILE OF DRAWING SENT BY REISS TO MR. LADD.

The apparatus A is a square box of wood, the cover of which shows the membrane, *c*, on the outside, under glass. In the middle of the latter is fixed a small platina plate to which a flattened copper wire is soldered, on purpose to conduct the galvanic current. Within the circle you will further remark two screws; one of them is terminated by a little pit in which you put a little drop of quicksilver, the other is pointed. The angle, which you will find lying on the membrane, is to be placed according to the letters, with the little hole *a* on the point *a*, the little platina foot *b* into the quicksilver screw, the other platina foot will then come on the platina plate in the middle of the membrane.

The galvanic current coming from the battery (which I compose generally of three or four good elements) is introduced at the conducting screw near *b*, wherefrom it proceeds to the quicksilver, the movable angle, the platina plate and the complementary telegraph to the conducting screw *s*. From here it goes through the conductor to the other station B, and from there returns to the battery.

The apparatus B, a sonorous box on the cover of which is fixed the wire spiral with the steel axis, which will be magnetic when the

current goes through the spiral. A second little box is fixed on the first one, and laid down on the steel axis to increase the intensity of the reproduced sounds. On the small side of the lower box you will find the corresponding part of the complementary telegraph.

If a person sing at the station A, in the tube *x*, the vibrations of air will pass into the box and move the membrane above, thereby the platina foot *c* of the movable angle will be lifted up, and thus will open the stream at every condensation of air in the box. The stream will be re-established at every rarefaction. In this manner the steel axis at station B will be magnetic once for every full vibration, and, as magnetism never enters nor leaves a metal without disturbing the equilibrium of the atoms, the steel axis at station B must repeat the vibrations at station A, and then reproduce the sounds which caused them. *Any* sound will be reproduced if strong enough to set the membrane in motion.

The little telegraph which you find on the side of the apparatus is very useful and agreeable for to give signals between both of the correspondents. At every opening of the stream, and next following shutting, the station A will hear a little clap, produced by the attraction of the steel spring. Another little clap will be heard at station B in the wire spiral. By multiplying the claps and producing them in different measures, you will be able as well as I am to get understood by your correspondent.

I am to end, sir, and I hope that what I said will be sufficient to have a first try; afterwards you will get on quite alone.

I am, sir,

Your most obedient servant,

FRIEDRICHSDORF, 13–7–63. PH. REIS.

To Mr. William Ladd.

No. 19. BRITISH ASSOCIATION REPORT ON REIS.

Report of the Thirty-third Meeting of the British Association for the Advancement of Science in August and September, 1863; published 1864.

On An Acoustic Telegraph, by W. LADD.

This instrument consists essentially of two distinct pieces of apparatus; that for transmitting the signal has a small mouth-piece. On the right-hand side there is a finger key forming part of the circuit, and an electro-magnet, with a vibrating armature and binding screw to connect with one of the line wires. Within a case under a

glass cover is an elastic membrane, in the centre of which is fixed a platinum plate in connection with the finger key. A like piece of angular metal resting on three pins is so placed that the pin at the angle rests on the plate in the centre of the membrane, the other two resting in cups on its edge so as to allow a free motion on the points. In the body of the receiver box is suspended a soft-iron core surrounded by a coil of silk-covered wire, one end of which is in connection with a finger key and the other with the binding screw. The method of producing sound in the receiving instrument depends upon the fact that at the moment of magnetizing or demagnetizing a piece of iron there is an alteration in the arrangement of the particles which gives rise to a slight ticking noise. Having connected the transmitter by means of an insulated wire with the receiver, and the binding screws having been brought in connection with a battery of three or four elements, if the finger key on the transmitter be pressed the person at the receiving station hears the ticking noise. To convey a musical note or sound the operator places his mouth to the tube in front of the instrument and sings a note, when immediately the membrane begins vibrating in accordance with the note sounded, and at each vibration breaks contact between the pin and plate in its centre. This forming part of the circuit causes the iron core in the receiving instrument to be magnetized and demagnetized a number of times equal to the number of vibrations of the membrane, and so conveys to the receiver an impression of a musical sound. The finger keys and small magnet at the sides of the instruments are for the purpose of varying the methods of communication by the combination of single sounds, and can also be used with the other parts for the purpose of regulating the lengths of the notes and dividing them into varying portions, so as to form a sound alphabet somewhat similar to the signals written by Morse's telegraph.

No. 20. PROSPECTUS OF MR. ALBERT.

J. WILH. ALBERT,
Mechanician,
Frankfort on the Main.

FRANKFORT-A-M., August, 1863.

SIR:

I take the liberty of sending you the accompanying prospectus, begging you to give it your kind attention; it relates to the very

interesting apparatus of Mr. Reis, for the production of tones with the aid of galvanism:—

THE TELEPHONE.

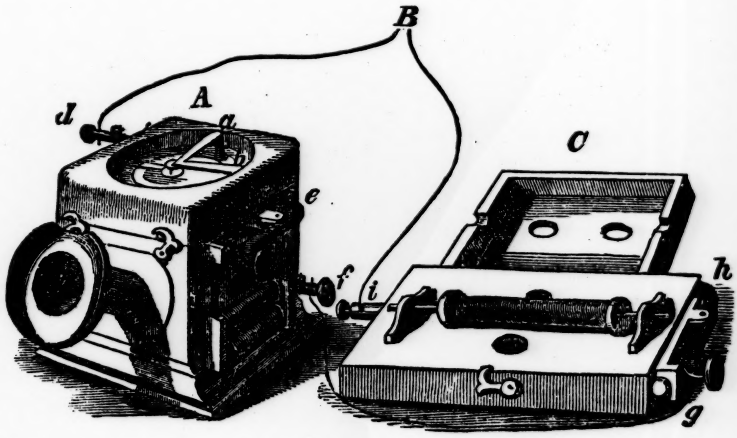
This apparatus, which can be had through me, is at all times exhibited for inspection in my warehouse, and besides I am quite willing to give every information regarding it. My warehouse of physical, optical, and chemical instruments and apparatus is now: Neue Mainzerstrasse-No. 34 AM. Taunusthor, only three minutes' walk from the several railroad stations, and therefore may be visited by any one, however short his stay in Frankfort may be.

Awaiting your kind order, I am,

Respectfully yours, J. WILH. ALBERT.

No. 21. CIRCULAR OF REIS.

(*This is on the same sheet of paper as the foregoing.*)



SIR:

Having succeeded two years ago in demonstrating the possibility of reproducing tones with the aid of the galvanic current and in manufacturing an apparatus for that purpose, the subject has been so highly appreciated by the most renowned men of science, and I have received so many encouragements, that I have striven since that time to improve my originally very imperfect apparatus, in order to give to others also the facility of experimenting.

I am now able to offer an apparatus which satisfies my expectations, and with which every physicist will succeed in repeating these

interesting experiments regarding the reproduction of tone (Ton = reproduction) at distant stations.

I believe that it is the wish of many that these instruments should come into the possession of laboratories; as, however, their manufacture demands a complete knowledge of the leading principles and a great experience in this matter, I have resolved to make the most important parts myself, and to intrust to the mechanician only the secondary parts and the external outfit. Mr. J. Wilh. Albert, mechanician at Frankfort on the Main, is commissioned to sell them. I have enabled him to offer them at the prices of 21 and 14 florins (12 and 8 Prussian thalers) in two qualities, which differ only in the external outfit. The instruments can also be had directly from me at the same price by cash payment. Every apparatus is examined by me before being shipped, and has attached my name, the serial number, and the date of construction.

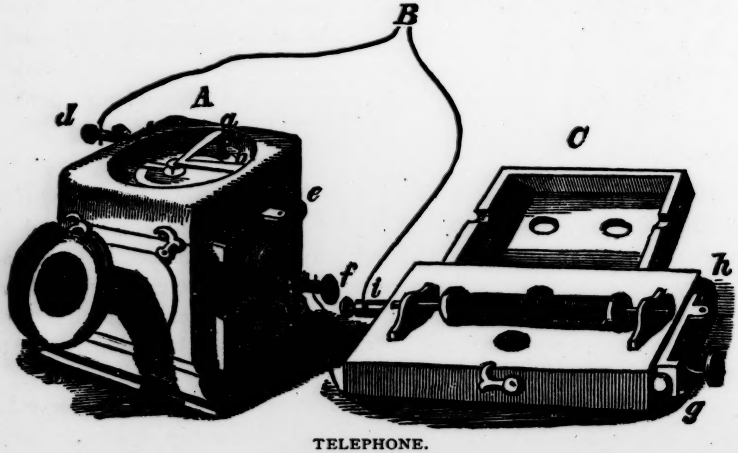
FRIEDRICHSDORF b. HOMBURG, v. d. HÖHE,
August, 1863. PHIL. REIS,
Teacher at L. F. Garnier's Boys' Institute.

(In manuscript on the foregoing is the following :—)

Descriptions of the above are to be found in Müller-Pouillet's Lehrbuch der Physik, Braunschweig, Vieweg & Son; Pisko, die Neueren Apparate der Akustik, Wein, Gerold's Son, 1865.

No. 22. REIS' DESCRIPTIVE CIRCULAR.

(*This and the foregoing are on two similar printed sheets.*)



TELEPHONE.

The apparatus consists of two parts, as may be seen in the wood-cuts above, the telephone proper A, and the reproducing apparatus C. These two parts are to be placed at such a distance from each other that singing or the sound of a musical instrument can be heard in no other manner except through the apparatus from one station to another.

Both parts are connected with each other and with the battery B, the same as in an ordinary telegraph. The battery must be sufficient to produce at station A the attraction of the armature of the electro-magnet placed at one side (three or four six-inch Bunsen cells are sufficient for several hundred feet of distance).

The galvanic current then goes from B to the binding post *d*, from there through the copper strip, to the platina disc in the centre of the membrane, then through the foot *c* of the angle towards the binding post B, *in the small hollow of which a drop of quicksilver is inserted.* From here the current goes through the small telegraph apparatus *e f*, then to the key of the station C, and through the coil surrounding *i* back to B.

If now sufficiently strong tones are produced before the mouth-pieces, their vibrations will put in motion the membrane and the angular little hammer [winkelförmige Hämmerchen] which lies on it; for every full vibration the circuit is once opened and again closed [einmal geöfnet und wieder geschlossen], and thereby are produced at station C in the core of the coil, just the same number of vibrations [ebensoviele schwingungen hervorgebracht] which are there perceived as tones or as combinations of tones [accords]. By placing the cover tightly over the axis of the coil the tones at C are greatly strengthened. Besides the human voice [menlischen stimme] there can be reproduced (according to my experience) just as well the tones [töne] of good organ pipes from F to C and those of the piano; to that end the box *a* must be placed on the sounding-board of the piano; out of thirteen chords a skilled experimenter could make out ten clearly. The telegraph apparatus placed on one side is evidently unnecessary for the reproduction of tones, but it is a very useful addition for convenient experimenting. With its aid it is possible to easily and surely make one's self intelligible [sich verständigen] with the person at the other station.

This may be done somewhat in the following simple manner: After the apparatus has been put up completely one satisfies one's self of the continuity of the connection and the strength of the battery by opening and closing the circuit whereby at A is heard a striking of the armature and at C a very perceptible ticking of the coil.

By a quick succession of makes and breaks at A, C is asked whether he is ready for experimenting, whereupon C answers in the same manner.

By agreement between the two stations simple signals can be given by opening and closing the circuit 1, 2, 3, or 4 times, *e. g.*, one stroke — sing: two strokes — speak, &c.

I telegraph words by numbering the letters of the alphabet and communicating their numbers.

1 stroke A,
2 strokes B,
3 strokes C,
4 strokes D,
5 strokes E, &c.

Z would consequently be indicated by 25 strokes.

But these numbers of strokes would take too much time and not be sure in counting. Therefore I put a dactyl for every 5 strokes, hence

—U U for E,
—U U and 1 stroke for F, &c.

Z:–UU–UU–UU–UU–UU, which is quicker, and more easily executed and better understood.

Still better is it to indicate the letters by numbers which are in inverse proportion to the frequency of their occurrence.

9 August, 1863, Friedrichsdorf, near Homburg, v. d. Höhe.

PHIL. REIS,
Teacher of A. L. Garnier's Boys' Institute.

No. 24. BÖTTGER'S ACCOUNT OF REIS IMPROVED APPARATUS.

Dingler's Polytechnic Journal, Vol. 169, p. 399.

CONCERNING THE IMPROVED TELEPHONE.

In the meeting of the Physical Society, held on July 4th, at Frankfort-a-M., a member of the society, Mr. Philip Reis, from Friedrichsdorf, near Homburg before the Heights, exhibited some of his improved telephones (Apparatus for the Reproduction of Tones at any desired distance by means of the Galvanic Current). It is two years since Mr. Reis first gave publicity to his apparatus, and although the performances of the same in their simple primitive form were astonishing, yet they had this great defect, that experimenting with the same

was possible only for the inventor. The instruments exhibited in the above-mentioned meeting scarcely reminded one of the earlier forms.

Mr. Reis has striven to give the same a form pleasing to the eye, so that they now will worthily fill a place in every physical cabinet. This new apparatus can now be easily managed (worked) by every one, and works with great certainty. Melodies sung quite lightly at a distance of about 300 feet were reproduced by the instrument set up much more distinctly than formerly. The musical scale was especially sharply reproduced.

The experimenters could even reproduce words, although, indeed, only such as had been often heard by them.

In order now that others, less experienced, may be able to even make themselves understood through the apparatus, the inventor has fixed at the side of the same a small, yet, according to his explanation, entirely sufficient arrangement, whose speed of communication indeed is not so great as that of the more recent telegraphs, but which works very surely, and assumes no especial skill in the person working it. We would call the attention of gentlemen busying themselves with physics to the fact that the inventor now has this interesting apparatus manufactured for sale under his supervision (the principal [important] parts he makes himself), and the same can be had of him directly or through the instrument maker, Wilhelm Albert, at Frankfort-on-the-Main, in two qualities, differing only in outward finish, at 14 and 21 florins, respectively (Böttger's Polytechn. Notizblatt, 1863, No. 15).

No. 25. REIS IMPROVED APPARATUS.

Fortschritte der Physik, 1863, page 96.

Ph. Reis Improved Telephone (DINGLER, CLXIX., 399.)

Herr Reis is said to have improved, quite essentially, his telephone. With the former instrument, experimentation was possible at the hands of the inventor himself, only.

The instrument (to be had at Albert's, in Frankfurt-a-M., for 14–21 fl.) has now, it is reported, a shape more pleasing to the eye, and can be operated easily by any one. At a distance of 300 feet tunes were reproduced far more distinctly than ever before. The scales are reproduced with peculiar precision. The experimenters were able even to communicate words, only such, however, as had been already often heard by them.

No. 26. GARTENLAUBE REIS IMPROVED APPARATUS.

(*The "Gartenlaube," No. 51, December, 1863.*)

THE MUSICAL TELEGRAPH.

The surprising results in telegraphing have often excited the question whether it may not be possible to communicate the language of sound itself to a distance. The trials made in this direction had till now produced no satisfactory results, because the vibrations of sound-conducting bodies soon diminish so much in force that they are no more perceptible for our senses.

People, perhaps, had already thought of a reproduction of sound at certain distances with the aid of the electric current, but those who have been the best fitted to attack the question, by their knowledge and resources, were the ones who doubted the most of a practical solution of that question. Those who are but superficially acquainted with natural science do not see the many difficulties this problem offers, if they are at all acquainted with it. Thus, about eleven years ago, a young man, Mr. Philip Reis, at present teacher of natural science at the Garnier Institute for Boys, at Friedrichsdorf, near Homburg, had the hardihood to work at the solution of this problem. But soon he was obliged to desist from it because his very first effort seemed to convince him of the impossibility of a solution. Later, however, after further studies and many experiments, he saw that his first effort was but a rudimentary one, and by no means convincing. However, he did not recommence to attack the question seriously for some time, not feeling himself strong enough to vanquish the obstacles on his road, although he never banished his early idea entirely from his thoughts.

How can a single instrument reproduce simultaneously "the combined effects of all the organs active in human speech?" This seemed to him the chief question. Later he put this question more methodically: "How does our ear perceive the composite vibrations "of all the organs of speech acting at the same time?" or, expressed more generally, "How do we perceive the vibrations of several bodies "sounding simultaneously?" If we throw a stone into quiet water there are produced on the surface uniform waves which progress symmetrically outward; the further they go the weaker they become, till they finally disappear.

It is quite similar with that what we call sound and tone. A body made to vibrate through any impulse affects the surrounding air, and causes waves in it, which follow each other at the same rate as the

vibrations of the body. As those rings on the water consist in swellings and depressions, so also the vibrations of the air consist of alternate condensations and rarefactions. If they reach our ear every condensation presses the tympanum towards the interior of the cavity, and puts in motion the adjacent group of small bones which communicates the motion to the liquid of the cochlea, in which the auditory nerves terminate. The latter are excited and produce the *sensation of sound.*

Now, if the waves of vibration follow regularly and with a certain swiftness (sixteen in the second at least), we shall have the sensation of a musical *tone.* The latter is the *higher* the quicker the condensations follow each other and the louder the *stronger* or higher the waves rise, as it were.

Our ear cannot perceive anything except condensations and rarefactions, wave crests and wave hollows. And, nevertheless, we receive the most varied auditory impressions, we distinguish the sound of the voices, we hear at the same time in quite different directions and can distinguish the different sources; nay, in a complete large orchestra, each of the numerous instruments is specially noticed by its peculiar sound, so that we decompose at every moment the total impression into its several parts, according to the height and depth, strength and weakness, or according to the timbre (or quality) [Klangfarbe].

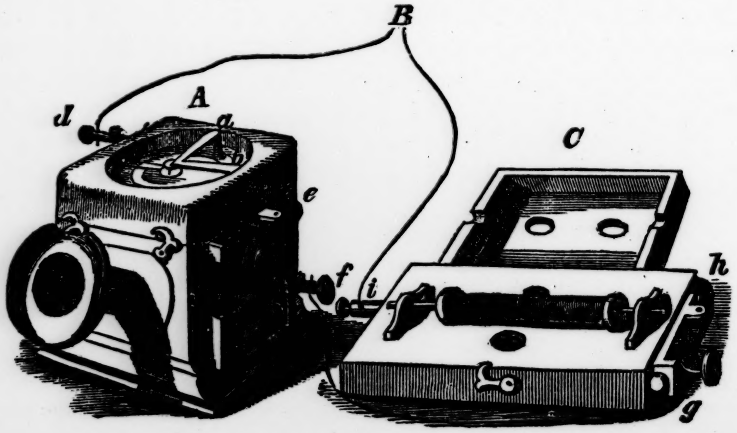
Referring to our simile, this is about the same as if we throw two or more stones at different places into a calm pond. The wave lines cross each other, strengthen each other at some points, weaken each other at others, and the surface has a ruffled, hillocked aspect. But, nevertheless, our eye can detect the different systems of rings, and can trace them back to their several causes. If we succeed in transmitting with the galvanic current the oscillations of a sounding body to a distance, so that there another body is put to equally rapid and, in respect to each other, equally strong oscillations, the problem of "telephoning" is solved.

For then exactly the same phenomena of waves are called forth on the distant points as the ear receives at the place of origin; therefore they also must make the same impression. The ear will distinguish at the distant points not only the single tones, according to their varying height and depth, but also to the proportionate force of the vibrations, and not only single melodies, but the performance of a whole orchestra; yes, even speech must be heard at the same time in places very distant from each other. Mr. Reis was the first one to

prove by experiments the possibility of solving this problem. He has succeeded in constructing an apparatus to which he gives the name *Telephone*, and which enables one to reproduce tones, with the aid of electricity, at any given distance. Already, in October, 1861, he made rather successful experiments with a very simple, rudely made apparatus, before a numerous audience at Frankfort. On July 4th of the present year he presented an essentially improved apparatus at an assembly of the "Physical Union," which transmitted by closed doors and windows a melody sung moderately loud, to a distance of about three hundred feet, so that it could *be heard plainly*.

In order to give an opportunity to larger circles, especially to scientific men, to convince themselves of the efficiency of this essentially improved apparatus, Prof. Böttger of Frankfort-a-M. made lately (at an assembly of German physicists and doctors in Stettin, in the sectional meetings for natural sciences) several experiments which certainly would have been crowned with still more success if the hall in which the session was held had been located in a less noisy part of the city and filled with a less numerous audience.

Although, for the present, we are not so far along as to be able to converse with a friend at a distance of several hundred miles, so much at least is certain, that with the aid of the telephone songs of all kinds, melodies, especially in the middle registers, can be reproduced most clearly at unlimited distances. These wonderful results are obtained with the following simple apparatus, which we show here in one-fourth of its size:—



A small box A (the telephone proper), a kind of hollow cube, has a mouthpiece S on the front side, and a somewhat smaller opening on the upper side of the box. The latter is closed with a fine membrane (skin from the intestines of a hog) tightly stretched. A narrow strip of platina *m*, connected with the screw post *d*, touches directly the membrane on its centre; a slender platina point *k*, attached to the angle *a b*, touches the strip of platina which rests on the membrane. If one sings into the mouthpiece S (by filling the same entirely with the mouth) the thin membrane vibrates and the attached platina strip receives likewise a vibrating motion so that it is alternately pressed against and leaves the platina point *k*.

From the binding post *d* which communicates with the platina strip resting on the membrane a conducting wire is connected with one of the poles of a galvanic battery B (about three to four six-inch Bunsen elements), and then the electricity is led through a wire attached to the second pole of the battery to the distant station C; there at *i* it passes through a coil *l l* formed of copper wire covered with silk thread, then back again to screw *f*, and there to the platina point *k*. At every vibration of the membrane an interruption of the electric current [Unterbrechung des electrischen Stromes] takes place by the platina point parting from the platina strip.

Within the wire coil at station C is a thin iron wire (a strong knitting needle) which is about ten inches long, and which with its two ends projecting out of the coil for about 2 inches, each rests on two bridges of a sounding box. This is the *reproducing* apparatus.

At every interruption of the current [Unterbrechung des Stromes] in the coil the iron rod is made to vibrate. If the motions follow with a certain rapidity they produce a tone which is rendered audible by the sounding box. As the rate of the interruptions depends on the pitch of the tone that has been sung into the mouthpiece, the same tone is sounded with the same pitch from the sounding box. The length of the circuit has no influence upon this. It is true the electric current loses force the farther it goes, but there is no reason why relays should not be employed, the same as in telegraphing, and with their aid any number of reproducing apparatuses be set into simultaneous vibrations. Mr. Reis has endeavored to give to his improved apparatus a form which should also be pleasing to the eye, so that it might fill worthily its place in any physical laboratory. He has applied, moreover, to the side of the telephone, as well as to the reproducing apparatus, a small telegraph arrangement, which is a very good addition for convenient experimenting. (It is indicated

in the drawing by the letters *e f h g*.) By alternately opening and closing the circuit with the key *e* or *h* the most varied signals may be given after mutual agreement; for instance, if one is ready for singing; if everything has been understood; whether one should stop singing or commence anew, &c.

Mr. Reis himself manufactures the principal parts of the telephone, for which no small amount of physical knowledge and experience is necessary. The mechanician, Wilhelm Albert, at Frankfort, is charged with manufacturing the less important parts and the external outfit, as well as with the sale of the instrument at a low price.

NO. 27. COSMOS DESCRIPTION OF REIS.

"Cosmos," Vol. XXIV., pages 349, 352. Printed and published at Paris, March 22, 1864.

GENERAL PHYSICS: ACOUSTICS.

The Acoustic Telegraph or Telephone of Mr. Philip Reis.

In 1837 Mr. Page observed for the first time the phenomenon of the production of sound by electricity, when the poles of a magnet were rapidly brought near to and moved away from a helix or conducting wire through which an electrical current was passing. M. Delezenne produced an analogous effect by turning an armature of soft iron before the poles of a magnet. The particular phenomenon with a helix was observed separately by M. de la Rive and MM. Beatson and Marriani. Each of these physicists made upon this subject their own special remarks. M. de la Rive attributed the sound produced to the kind of shock which took place upon the sudden displacement of the molecules at the moment when the current produced its appropriate action. It would therefore be possible to increase the intensity of the effect produced by multiplying the intermittences in the passage of the current. It is in this way that the learned professor of Geneva was able to produce a sound both clear and prolonged, from a cylindrical mass of iron ten centimetres in diameter and weighing ten kilogrammes. M. Marriani recognized, on his part, that the sound created by a bar of iron placed in these conditions was the same as that which it would give forth if it was thrown into vibration by blows which affected it at its extremity. None of the magnetic metals produced any effect of the kind. As to the coercitive force, M. Marriani establishes that a bar of steel, well tempered, would make no sound, but that on the contrary the phe-

nomenon manifested itself when it was annealed. M. Marriani and M. de la Rive observed also that an intermittent current passed through a stretched wire made it produce a sound identical with that which it would give forth if it were placed in the interior of a helix. According to M. de la Rive the sound was more intense as the wire was made shorter and according as its electrical resistance came nearer to that of the battery employed.

M. Wertheim rendered sensible to the ear the vibrations which result from the passage of a discontinuous electric current through a rigid bar.

In these various experiments, in addition to the musical sound, the observer perceived a succession of blows (*battement*) which coincided with the interruptions of the current. M. de la Rive compared them to the noise which drops of rain made on falling upon a metal roof. These successive blows would even be obtained on operating upon magnetic metals reduced to a powder. M. de la Rive explains this: the sound produced by iron when the current passes in the magnetizing helix is explained by M. de la Rive as follows:—

"The current tends to place the molecules of the iron in a longi-"tudinal direction; these tend to return afterwards to their normal "position, hence the vibrational movement which gives rise to the "sound."

It is on the basis of these facts that Mr. Reis has constructed the telephone or acoustic telegraph. Fantastic minds have singularly exalted the qualities of this apparatus; they have undertaken to indicate for it at once an office which it is far from being able to fill. The exaggerations of these illusions have been demonstrated to us by experiments which we have just made at Mr. Koenig's establishment with an apparatus constructed in Germany, under the supervision of Mr. Reis. This physicist has constructed his telephone in the following manner:—

The transmitter (manipulator) is represented by a rectangular hollow box. One of the sides of this is provided with a flaring opening, intended to receive the note which was to be transmitted. The upper surface of it consists of a membrane suitably stretched, on the centre of which is fixed a strip of platinum, which is in electrical connection with one of the poles of the battery. Above this there is placed a second and movable strip which, when the instrument is not in operation, rests on the first by a fine point, making contact by a fine point, also of platinum. It will readily be understood that if the membrane vibrates, it will throw up into the air the movable

strip, which will again fall back into place. Hence oscillations which will correspond in number exactly with those of the membrane. The receiver is composed simply of a magnetizing helix, in the interior of which is placed a bar of soft iron; the whole is mounted on a resonating box. When the apparatus is to be operated, these two instruments are placed in the circuit with an ordinary line battery. The operation of the instrument is easy to understand. The vibrations which the operator placed in front of the mouth-piece impresses upon the air enclosed in the box of the transmitter are repeated by the membrane; and just as a style fixed on this membrane (as in the phonautograph) would write these vibrations upon a paper covered with lampblack, so in the same manner the electrical contacts are successively established and broken between the two strips of platinum. Hence there is caused in the coil of the receiver a number of intermittences or interruptions in the passage of the current, which is necessarily equal to the number of vibrations of the membrane of the transmitter. Now, since each intermittation causes one single shock, a series must necessarily produce a sound identical in pitch with that produced at the mouth-piece of the transmitter. Would not the telephone of Mr. Reis be an admirable instrument if it realized absolutely the promises which its theory holds out? Without prejudging the future, we must recognize that it has not yet done so. When one sings the musical scale at the transmitter, there needs an ear well trained to distinguish the sound repeated by the receiver in the midst of the vibrations which agitate it. For ourselves we have been only able to recognize the successive rise and pitch of these rapid roulades; but perhaps a trained musician would be able to recognize amongst them a dominant note. The model, however, of which we speak did not, and had in its construction several causes of error; and Mr. Koenig, so justly recognized in matters of acoustics, intends to study out the improvements of which this telephone is susceptible.

Let us mention some of the principal of these causes of error: It may be that the membrane will not at every moment vibrate with the same degree of amplitude, and this will consequently occasion sometimes a failure to make contact; if the sound produced by the operator at the transmitting end does not vary much, the contact may be prolonged. The remedy for this defect is in substituting for the voice of the operator a tuning-fork, arranged to vibrate, for example, by a battery; then a note would be produced which would be better defined, but always very feeble. As to improvements which would

be of a nature to render this telegraphic apparatus practicable, Mr. Koenig is well fitted to find them. We already know certainly that the intensity of the sound increases as a softer iron is used, because in that case the molecules have more freedom of motion than they had in the hardened iron or in steel. If the iron core is magnetized by the influence of a permanent magnet, or by another coil, its sound is more intense when the intermittent current is sent in such a direction as to produce a demagnetizing effect upon it, and it is less intense when the current is sent through the helix in such a direction as to increase the magnetism. The reason is, that in this last case the molecules are in advance, in a position already very near that which the current can compel them to take. Too much tension in the core also makes the sound more feeble, for the molecules having been already placed in a forced position, are less free to receive further motion. The electrical transmission of musical sounds is therefore a problem, of which the true solution has not been found; and all the magnificent promises which have been made and published on the subject of acoustic telegraphy seem to us still to belong to the region of illusions.

No. 29. KOENIG'S DESCRIPTION OF REIS.

From KOENIG'S "*Catalogue des Appareils d'Acoustique*," *Paris, 1865, page 5.*

29 TELEPHONE OF M. REIS. 60 FR.

This apparatus is intended to transmit sounds to a distance by means of electricity. It rests upon the fact demonstrated by the preceding apparatus. [*The preceding apparatus was the Wertheim coil and core, which Reis uses for a receiver.*]

At the first station the current traverses a little band of platinum, which is attached to a membrane in such a way as to follow all its movements, and of a very movable point, which rests lightly upon this membrane. At the other station the current traverses a coil, at the centre of which is a bar of soft iron. If now we produce before the membrane a sound which causes it to vibrate, each vibration in pushing away the point from the platinum plate will produce an interruption of the current. On the other hand, each making of the current will produce in the bar of soft iron at the second station a momentary and weak sound. It is the rapid and isochronous succession of these sounds, all acting in simple blows, which produce the

continuous sounds that are heard. It is true that they are not of good quality, and that they cease from time to time. This comes from the fact that the membrane does not vibrate equally well for all tones, and because the manner in which the vibrations determine the interruption of the current, by pushing the little point away from the plate, is far from being perfect.

No. 30. PISKO'S DESCRIPTION OF REIS.

PISKO. *Die neueren Apparate der Akustik. Vienna, 1865, pp. 94 et seq.*

[Page 94.] *a.* 51. *Principle of the Telephone of Reis.* The "Tele-" phone" of Reis (Fig. 60) is related to the Membrane-Phonautograph. The round end *s* of a light strip of platinum *n s* is fastened upon the membrane *m m* with wax in such a way that the strip of platinum can make all of the vibrations of the membrane with it. Very near to this end *s* of the strip of platinum *n s* is a platina point fixed so that it is touched by the strip of platinum as this vibrates with the membrane. If we suppose the outer end *n* of the platina strip and the platina point to be connected with the poles of a battery, then a current is established or broken by the vibration [page 95] of the membrane, according to its phases. A magnetic piece of clockwork or an electro-magnetic telegraph introduced in this circuit would transmit to a distance indications that some one was speaking, but they would, self-evidently, not be able to make known what was spoken.

b. It is well known that an iron wire, surrounded by strong galvanic currents frequently broken, is made to sound forth tones which may be longitudinal or transverse, or both at the same time. Reis introduced such an iron wire lying in a multiplying coil at the second station C. This produced tones, if the membrane was caused to vibrate by singing or talking into (S, Fig. 60) the hollow, cubical part A. In my experiments with the telephone the rod never changed its pitch even with the most different tones and sounds, and always produced only the rhythm of the words sung or spoken at S into the part A. The aria of the song sung into the instrument could generally be recognized from the rhythm. The experiments, with special reference to this, are recited in § 53. But this much is evident already, that time must yet elapse before the simultaneous concerts and singing productions so ardently hoped for by the newspapers. The apparatus of Reis is indeed a "Telephone," but not a

"Phonic Telegraph." The only means of transmitting song and speech, and this only for moderate distances, is the old well-known speaking tube. But the experiment of Reis can always be classed with the most beautiful and interesting of school experiments; and as the means for producing it are simple, the apparatus of Reis will surely soon find its way even into moderately endowed institutions. That the sounding of the wire in the telephone is not due to acoustic transmission can be shown by cutting the coil out of the circuit; the sounding ceases at once.

1. Reis' phonautograph was originally made of a wooden cube with a conical cavity. The smaller opening was covered with the membrane. A knitting-needle was used as the sounding wire, which projected about 2 inches out of each side of the multiplying coil, and rested upon two bridges of a resonance box. The surrounding [page 96] coil consisted of six layers of fine wire. Fig. 60 shows the telephone as it is at present manufactured, according to the inventor's directions, by artisan Albert, in Frankfurt, and artisan Uanck [Hauck ?], in Vienna.

2. Even though the telephone cannot be used to reproduce concerts, this can be accomplished for moderate distances by the resonance of solid bodies, in narrow limits, to be sure. Pepper, director of the Polytechnic Institute, formed at London for amusing sciences, gave such a concert (18 5) with Wheatstone's method. Four of Erard's harps stood upon the stage. Each had on its resonance board a short staff of pine 2 cm. thick.

By turning the harps on their axes this staff was made to touch an exactly similar one, which went into a deep cellar, and there was in contact respectively with the sounding-board of a piano, of a violoncello, of a violin, and the mouth-piece of a clarinet.

As long as the resonance staffs touched, the concert was heard distinctly; but as soon as one or all the harps came out of contact with the sound-conducting staff, the music ceased. The character of the instruments played was, as a whole, preserved, only the violoncello tones being somewhat raspy.

52. *Particulars regarding the Telephone.*

(*a.*) It consists substantially of

1. The transmitter A.
2. The receiver C.
3. The battery B, and finally of
4. The conducting wires.

(*b*.) The transmitter A is essentially a parallelopipedic body of wood. Its upper part *u x* is cut out of one piece of square section, the side *z x* measuring 9 cm., its height *u x* 2.8 cm.

This part can be moved on the lower box A A by means of hinges. If we turn back the cover *x u* we shall notice a small circle cut out in it 3.9 cm. in diameter. A brass ring, with a margin 8 mm. broad, fits unto this hole, which is furnished with a groove like a pulley.

Over the ring the membrane *m m* is stretched by a silk thread lying in the groove of the same. This circular membrane is surrounded by a wider circular hollow *b* b^1 8.5 cm. A shovel-shaped strip of platinum *n s* is placed in connection with the brass binding post *d*, and rests by its circular piece *s* on the centre of the membrane.

By means of sealing-wax this circular part is fastened to the membrane, and is thereby compelled to accompany the membrane in its vibration. The farther transmission of the galvanic current from the centre of the membrane takes place by means of the brass angle *a s b* (D, Fig. 60). This rests at *s*, by means of a platinum or steel point, upon the conducting platinum strip, *n s*, and dips at *b* with a platinum or steel point in a mercury cup which is made in a screw transmitting the current. The point *a* serves only as a base or support for the angular piece *a s b*, which in general is supported like a tripod, in order that the contact-point *s* should remain as constant as possible. The angle *a s b* is simply pushed over a projecting pin by a hole at *a*, until it remains resting on a broader lower part. From *b*, the electrical conductor with a covered wire extends to the brass key *e* (A, Fig. 60), and from there further in the direction indicated by the arrow.

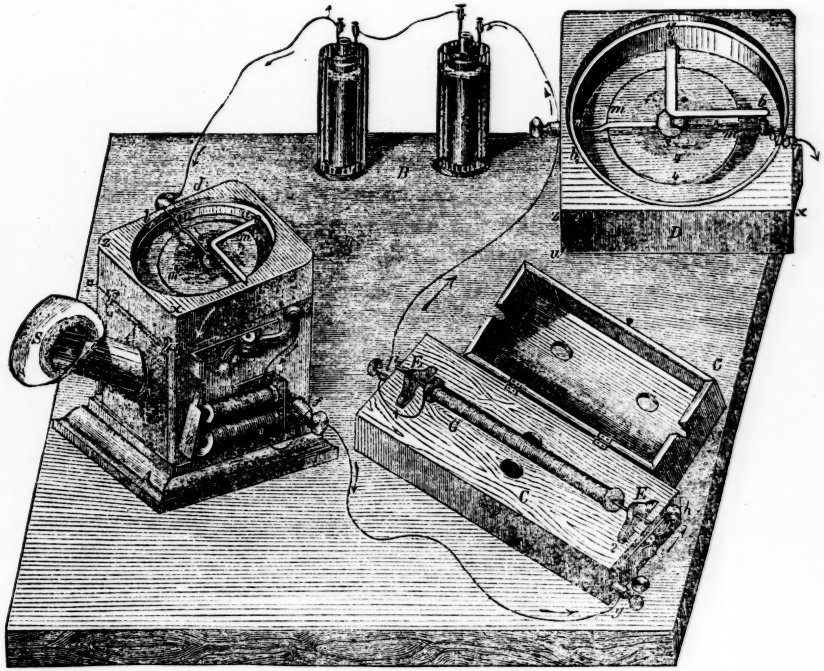
The under part A A of the transmitter is constructed of wooden boards and forms a parallelopipedon whose height = 6.8 cm., and whose breadth = 7.7 cm. For the reception of tones there is the slanting attachment S made of tin with a funnel-shaped enlargement.

The longer side of this enlargement is 6.7 cm., the shorter 4.7 cm.; the vertical diameter of the enlargement measures 7.15 cm., the horizontal diameter 7.5 cm., and finally the diameter of the narrower cylinder 3.9 cm.

It is plain that, if necessary, the platinum strip can be replaced by a thin strip of brass, and the platinum or steel points by iron ones. Only then the contact-points must oftener be cleaned to a metal polish.

(*c*.) The receiver is in general a double resonance box, whose upper part, "the cover," is movable on two hinges and can be laid back. The length of this cover is 16.4 cm., its width 9.5 cm., and its height 3.2 cm. The length of the under box measures 22.9 cm., its width 9.6 cm., and its height (98) 2.5 cm. The under part of the resonance

465. 466



only with the reproduction of the rhythm of the respective song or words.

(*b*.) The transmitter A is essentially a parallelopipedic body of wood. Its upper part *u x* is cut out of one piece of square section, the side *z x* measuring 9 cm., its height *u x* 2.8 cm.

This part can be moved on the lower box A A by means of hinges. If we turn back the cover *x u* we shall notice a small circle cut out in it 3.9 cm. in diameter. A brass ring [illegible] broad, fit
pulley.

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(*c.*) The receiver is in general a double resonance box, whose upper part, "the cover," is movable on two hinges and can be laid back. The length of this cover is 16.4 cm., its width 9.5 cm., and its height 3.2 cm. The length of the under box measures 22.9 cm., its width 9.6 cm., and its height (98) 2.5 cm. The under part of the resonance box has two wooden bridges, which are separated from each other 17.4 cm., and serve as supports for the iron needle, which is 21.5 cm. long and 0.9 mm. thick, and intended to produce the tones. The length of the spiral placed over the needle and designed for producing the electro-magnetism is 15 cm. The wooden covers of both parts must be constructed as thin as possible, and the greatest breadth of the circular holes seen in the figure measures 13 mm.

(*d.*) One can successfully use as a battery a small four-cell Smee's or two larger Bunsen's cells. The conducting line must be made at least so long that the exciting tones can no longer be heard through the wire. For corresponding between the two stations, the inventor has arranged the electro-magnetic telegraphic apparatus *e v g h*, easily seen and understood from the figure. Agreement can be easily had as to the corresponding signals, and it is simplest to accept the signs given by the inventor. (26.)

The receiver C gives, on tapping with the key *e*, the corresponding signals by the rod *e e* giving out tones, while at the transmitter A the electro-magnet *v* announces the signals by means of the spring armature *z*.

53. Experiments with the telephone.

(*a.*) As soon as one brings his mouth to the funnel S, and sings, the membrane of the transmitter A falls into corresponding vibrations, and the little iron rod *e e* at the second station begins to give out tones. Every time that a spark is visible at the first station, at *s*, the rod certainly sounds at the other station. The same is true when the peculiar buzzing tone is perceived, which arises from the striking of the vibrating platinum strip upon the point of the angular hook resting thereupon. The appearance of these sparks, or of the peculiar buzzing at the transmitter A, announces to the observers at the station A that the rod at C is giving forth tones. Tones and melodies, which were sung into the sound-opening S, and especially clangs in which the teeth and head-bones also vibrate (the so-called humming tones), always produce a toning of the rod or needle E E, and indeed, as already mentioned (§ 51), without change of pitch, only with the reproduction of the rhythm of the respective song or words.

The pitch of the tone excited at C in the rod *e e* was, in the apparatus at my disposal, *h'*: its strength not very remarkable and its quality (Klang) buzzing like that of the tone of a weak-sounding reed-pipe (something like a child's trumpet). The skin lying about the pericardium of the smaller and even the larger mammals (calves, &c.) makes the best membrane—gold-beater's skin reproduces only the lower tones.

The cover of the resonant box seemed superfluous in my apparatus, and the tone was indeed somewhat stronger without the cover.

1. In experiments with the telephone, close attention must be paid to seeing if the end *s* of the platinum strip still sticks to the membrane, and, if necessary, it must be pressed upon the membrane. When this leaf will no longer cling, a knife blade is heated, a piece of sealing-wax touched with it, and the melted wax thus transferred to the under side of the round end of the platinum strip *n s*. Immediately thereupon it is pressed on to the membrane *m m*.

2. From a long line of experiments, which I have performed with the telephone, I take the liberty of giving here some results:—

(*a.*) A Cagniard-Latour siren with upright axis, blown near the opening S from the lowest to the highest tone, gave no result. Only when the rotating plate was turned directly toward the funnel-shaped sound-receiver S, and brought very near the same, was it twice possible with the medium tones of the siren to hear two short tones of the iron rod *e e* of the pitch h^1.

(*b.*) A tuning-fork with normal tone a^1 aroused no tone whatever in the receiver C, neither when in immediate vicinity of the sound-funnel S, nor when laid upon it.

(*c.*) A metal bell, which gave, according as it was rubbed with a strong bow, the tone h^1 or h^2, produced no results from the telephone, even when the bell was brought ever so near to the sound-reed S, or when laid upon it. Only when the tone h^1, by means of suitable resonant tubes, was very perceptibly strengthened, did the telephone respond weakly and shortly, and indeed again with h^1.

(*d.*) Wooden lip pipes belonging to the scale between c^1 and c^2, when they were laid with the walls of their reeds on the sound-funnel S and made to give out tones, were not able to bring the telephone to produce tones; but they were most active in respect to the telephone when the under open end of the reeds was brought immediately before or into the opening S of the sound-cylinder of the transmitter A; this position may be called the "first."

These pipes also worked successfully upon the telephone, when their mouths (the holes) were laid on the sound-conducting opening S. This position may, from now on, be called the "second." If the pipes in both positions were removed only a few lines from the sound-receiver S, the effective vibration of the membrane ceased, and, in fact, in the first position sooner than in the second. If, however, pipes of any material of different lengths (1 ft. to over 8 ft.) and different widths, were laid on the conducting-sound tube, and the former pipes applied to these in the first or second position, the telephone gave the same results as in the immediate use of the short transmitting tube.

(*e.*) The former pipes, when covered, caused (as was to be foreseen) the telephone mostly not to sound at all, or only interruptedly in the first position. In the second position the telephone was excited by them for the most part completely, seldom interruptedly.

(*f.*) I had at my disposal no pipes of the c^3 scale. Tones from the latter scale, which by strong blowing were excited in the pipes used by me, gave mostly no result, no matter what position was given to the pipe.

(*g.*) A reed-pipe of tone d^{-1} with open reed excited the rod of the telephone only when its open end was turned toward and brought near the sound-receiving funnel S of the transmitter. Increasing the tone by a resonant tube produced an interrupted tone. A like result was obtained with a reed-pipe of the tone c^{-1} with full beat reed, only here the excited telephone tone was constantly interrupted.

(*h.*) The miniature-normal-diapason (a small reed-pipe of the tone a^1, compare Chap. VI.) sunk into the sound-conducting reeds, so that the mouth lay on the funnel, produced a clear tone in the telephone when strongly blown.

(*i.*) Marches drummed at A with the key *e e* were produced by the receiver C, and in fact, always with the tone h^1.

(*k.*) Singing of different melodies was always successful; the rhythm of speaking was only interruptedly reproduced.

(*l.*) Whistling with the mouth into S had no effect, and the tone passed over into a higher one, probably because the vibrating column of air thereby became shorter. The tones f^1, g^1, a^1, fis^1, c^1, and cis^1, produced with the mouth by whistling passed over into fis^1, gis^1, b^1, g^1, cis^1, and d^1 respectively, as soon as the mouth lay immediately before the sound-receptor S.

There was a rise in tone of half a tone. Similar rise in tones is obtained by whistling into a cup, hat, &c. Indeed, the cutting off of

the current of air coming from the mouth by the flat of the hand raises the tone in such whistling, and this can be very easily recognized by moving the hand up and down.

(*m.*) Since the distinct buzzing of the platinum strip on the transmitter S is a sure sign that the iron rod *e e* is sounding at C, there is no need in this respect of telegraphic communication between the stations (§ 52, d).

(*b.*) If a comparison is made of the results of experiments with the telephone and those with the membrane-phonautograph, it will seem at first as if the latter did much too little in comparison with the former. This contradiction, however, rapidly disappears. The membrane-phonautograph also gives plain tone-writings of a melody in the space of an octave, together with double tones and chords, and according to Donders, still more. Moreover, in the telephone the membrane is moved not only by the vibrations of that tone, by which, according to the laws of sympathetic vibration, it can be brought into vibration, but it is also mechanically raised and lowered by the strong condensations and rarefactions arising from the exciting tone (singing, &c.) in the closed masses of air. Every condensation will press the membrane outward, even when its deepest normal tone is much higher than the exciting (sung) tone. Very strong and thick membranes might perhaps resist this purely mechanical excitation, but they would be then not sensitive enough for real sympathetic vibration. In many cases (for example, in drumming with the key on the box, in placing the apparatus A on the resonant cover of a piano, &c.) the vibration of the membrane in the telephone arises also only in the same way as the membrane in König's pipes for proving the nodes of vibration (compare a later paragraph). In this, also, the stretching of the membrane is not necessary in order that the latter may show outwardly the condensations and rarefactions of the air in the pipe.

Pipes with thin walls furnish a farther proof of this. The latter allow trembling to be felt when touched by the hand while the pipes are sounding; indeed, very thin walls deepen the tone somewhat, and thereby show that they are not able to resist the pressure arising from the condensations.

Sand sprinkled upon walls of this kind is thrown off from the nodal points. If, therefore, thin strips of wood are able to imitate in such a manner the vibrations of the air in the pipe, although the proper tone of the wall may lie far from the exciting tone, this is certainly much more the case with a membrane. The experiments with the pipes introduced in the previous paragraph also confirm this, for they only

then gave a result in the telephone when the open end or mouth of the pipes lay very near the sound-receptor, and even the experiments with singing confirmed this view. Just these experiments show the telephone weaker in comparison with the membrane-phonautograph, because in the latter, when the membrane is tuned for a tone, the tone-writing comes, whatever position the exciting tone may have had in reference to the sound-receiving side of the membrane-phonautograph, provided only it is near enough. And yet it would seem that to close the battery by means of the vibrating platinum strip on the membrane demands less strength than to move the little pen so that it may be able to remove the lampblack on the writing cylinder. The results of the few experiments with the telephone appear moreover to indicate that it might perhaps be more advantageous for the production of tone-writing by means of the membrane-phonautograph, to make the latter of smaller dimensions than has been the case up to the present. In fact, König is already busy on new arrangements for the membrane-phonautograph. König already hopes a better result for the written reproduction of simple sung melodies, if the wide opening of the paraboloid in the membrane-phonautograph be closed by a plate, which had a small opening for applying the mouth.

In any case, a renewed study of the laws of the sympathetic vibrations of the membrane with especial reference to both pieces of apparatus will be necessary. Many think that the membranes must vibrate sympathetically to every tone, because all the tones are heard by means of the membrane in the ear, but in this respect it is very important to note that, according to Professor Mach (27), this may be brought about by a proper accommodation-mechanism in the ear. For me this supposition of an accommodation, according to the varying tensions of the tympanum, has a high degree of probability bordering on certainty.

Philip Reis showed his apparatus for the first time in October, 1861, in a very primitive form to the Physical Society at Frankfort-on-the-Main; on July 4, 1863, to the same society he showed the form represented in Fig. 60. This time he experimented over a distance of 300 feet. Professor Böttger introduced the apparatus to the Naturforscher-Versammlung, at Stettin (1863), in the Physical Section.

No. 31. REIS PROSPECTUS—FROM PISKO.

PISCO's *Neueren Apparate der Akustik, Wien, 1865, p. 241.*

26. Here may be the place for the prospectus which the inventor,

Mr. Ph. Reis, attaches to the apparatus furnished by him, and made by the artisan, Mr. Albert, in Frankfort.

"*Telephon.*" Every apparatus consists, as can be seen from Fig. 60, page 96, of two parts, the telephone proper and the receiver C. These two parts are placed at such a distance from each other that the singing or toning of a musical instrument can be heard in no other way from one station to the other except through the apparatus.

Both parts are connected with each other and with the battery B like common telegraphs. The battery must be sufficient to bring about at station A the attraction of the armature in the electro-magnet fastened at the side (3-4 six-inch Bunsen cells are sufficient for several hundred feet distance).

The galvanic current goes from B to the post *d*, from here through the copper strip to the platinum-leaf on the middle of the membrane, then through the foot (at D, Fig. 60) of the angle to the screw *b*, *in whose small hollow a small drop of mercury is placed.* From here the current goes through the small telegraph-apparatus *e f*, then back to the key of the station C and through the spiral over *i* back to B.

If now sufficiently strong tones are produced in front of the sound-opening S, through the vibrations of the same, the membrane, and the angular-shaped little hammer lying upon it are set in vibration; the circuit is alternately opened and closed at every full vibration, and hereby are produced in the iron rod of the spiral at station C the same number of vibrations, and these are perceived there as tone or tone-combination (accords). By laying the upper box tightly upon the axis of the spiral the tones at C are very much strengthened.

Besides the human voice there can be produced (according to my experience) just as well the tones of good organ-pipes from F—c and those of the piano. For the latter purpose A is placed upon the sounding board of the piano. (Of thirteen common chords an experienced experimenter could clearly recognize 10.) As regards the telegraphic apparatus attached to the side, this is clearly unnecessary for the reproduction of tones, but it forms a very agreeable addition for comfortable experimenting. By this it is possible to correspond right well and surely with one's vis-à-vis.

This takes place somewhat in the following simple manner:—

After the apparatus is completely set up assurance is had of the continuity of the conductor and the strength of the battery by opening and closing the circuit, when at A the striking of the armature, and at C a very perceptible ticking of the spiral is heard.

By quickly alternately opening and closing at A it is asked at C if they are ready for experimenting, whereupon C answers in the same manner.

Simple signals can, by agreement at both stations, be given by opening and closing the circuit once, twice, three times, or four times, for example :—

1 stroke = sing,

2 strokes = speak, &c.

I telegraph words by numbering the letters of the alphabet, and then communicating their numbers :—

1 stroke = a,

2 strokes = b,

3 strokes = c,

4 strokes = d,

5 strokes = e, &c.

z would in this way be designated by 25 strokes.

This number of strokes would, however, waste time in representing, and would be difficult to count surely, wherefore I place a dactyl stroke for every five strokes, then we have,

—oo for e,

oo and 1 stroke for f, &c.

z = —oo —oo —oo —oo —oo, which is more quickly and easily carried out, and better to understand.

It is still better to designate the letters by numbers which are inversely proportional to the frequency of their recurrence.

No. 32. KUHN'S DESCRIPTION OF REIS.

Handbuch der Angewandten Elektricitätslehre VON KARL KUHN, *1865, pp. 1017–1021.*

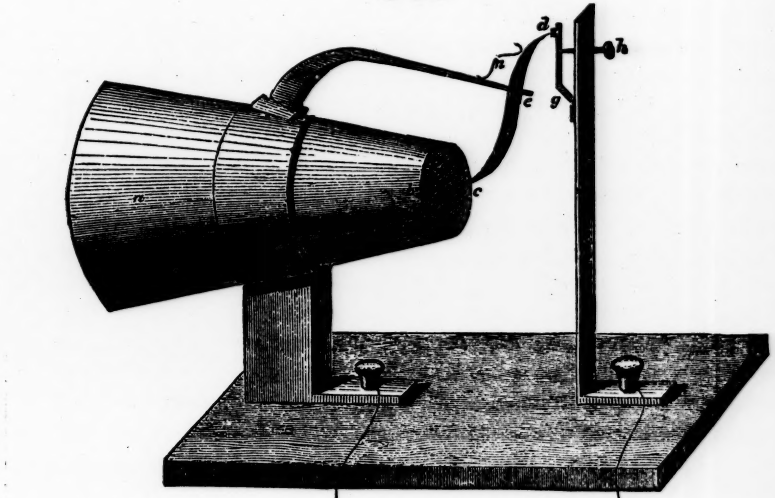
The experiments made by Reis in Frankfurt-a-M., on the 26th October, 1861, have proved, however, that when the breaks of the current [stromunterbrechungen] follow each other almost continuously and very quickly in a coil provided with a thin iron core, the iron wire can enter into longitudinal vibrations, and in this way be enabled to reproduce sounds of different pitch. An exact reproduction of the sounds does not take place, however, but only an imitation; for this reason it cannot be questioned here of transverse vibrations [transversal schwingungen]. A phenomenon [erscheinung] has otherwise been heard of, which belongs to the afore-mentioned class, in which the intensity and the timbre [klang] of the sound accom-

panying it (the phenomenon) depend among other things on the strength of the current [strom stärke] and on the number of breaks of the same, and in which, as it seems, the pitch of the tones also can vary under different circumstances. We can, however, hardly imagine by what arrangements it could be feasible to coax tones of any given height or depth out of an iron or metal tube split on one side, while it (the tube) is affected by the alternate currents of an induction apparatus the coil (rolle) of which surrounds it. Yet the possibility cannot be controverted that the principle of Neef's circuit-breaker [unterbrecher] might contribute to the solution of the problem in question. It has been employed for local purposes either with or without modifications in the study and investigation of acoustic phenomena. Thus Petrina has used the principle of Neef's circuit-breaker [unterbrecher] for his electric harmonica in this way that instead of the Neef hammer a little rod was chosen, the transverse vibrations of which rendered the tone. "There are four little rods of various length side by side, "the motions which are checked by means of levers managed by finger "keys." That principle was used previously by Dove, in a modified manner, to set strained strings and elastic springs into acoustic vibrations of constant amplitude by means of an electric magnet, and, in this way, to be enabled to investigate constant tones. It appears from Legat's published communications that "the ideas submitted by Ph. "Reis of Friedrichsdorf in the Physical Society and in the meetings of "the German Hochstift in Frankfurt-a-M. about the reproduction of "sounds by means of electricity" referred to arrangements of a similar kind. Legat mentions in his paper all that has been done thus far towards the realization of that project, and we borrow from it that part only which throws some light on the construction of a telegraphic apparatus with which it is said to be possible to produce vibrations and make sounds in any desired manner, and through which the employment of electricity is said to make it feasible to bring forth at any given distance vibrations similar to the first produced ones, and in this way to reproduce at a certain place tones originally produced at another place.

This apparatus is composed of a transmitter and of a receiver. The transmitter (Fig. 504, page 1019) consists in a conical tube *a b* about 15 cm. long, 10 cm. at the front, 4 cm. at the back opening; the choice of the material as well as a greater length is indifferent; a greater width, on the contrary, is disadvantageous; the surface of the interior must be as smooth as possible. The narrower back opening is closed by a membrane of collodion *o*, and on the middle of the

circular surface formed by this membrane rests one end *c* of lever *c d*, the fulcrum of which is held by a support and remains

Fig. 504.



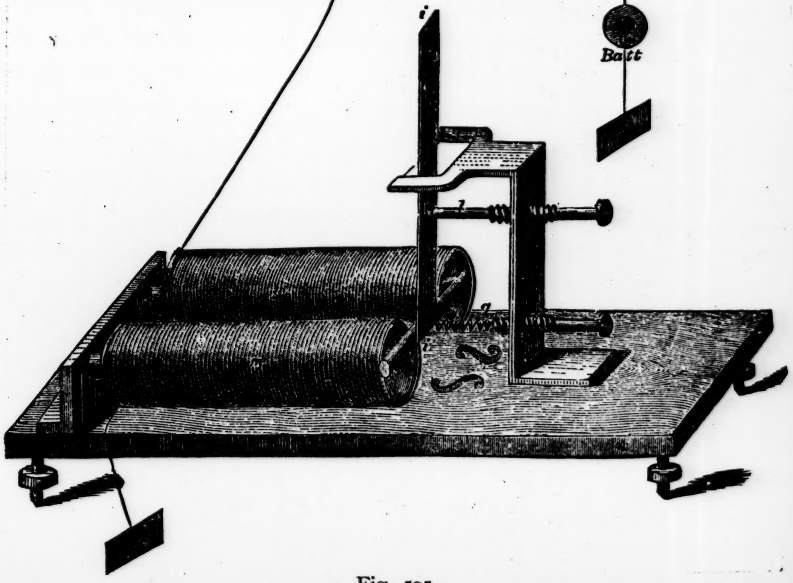


Fig. 505.

connected with the metallic circuit. This lever, one arm *c e* of which must be considerably longer than *c d*, should be as light as possible so as to follow easily the motions of the membrane, as an uncertain obedience [folgen] on part of lever *c d* would produce imperfect tones at the receiving station. In the state of rest, the contact *d g* is shut and a weak spring *n* holds the lever fast at rest. On the metallic support *f* which is connected with one of the poles of the battery is a spring *g*, with a contact which touches the contact of lever *c d* at *d* and the position of which is regulated by screw *h*; over tube *a b* a disk must be placed which encircles the outer circumference of the tube closely, so that the efficacy of the apparatus may not be impaired through the effect of the air waves coming round and striking against the rear end. This disk at right angles with longitudinal axis of the tube measures about fifty (?) cm. in diameter. The receiver (Fig. 505) consists of an electro-magnet *m m* which rests on a sounding board, and the coil of which is in connection with the metallic conductors, and with the ground. Opposite the electro-magnet is an armature connected with a lever as long as possible, but light and broad, which latter, with the armature, is fastened pendulum-like on the support *k*. Its motions are regulated through screw *l* or spring *o*. "In order to increase the efficacy of the apparatus, this receiver can be placed in one focus of an ellipsoidal enclosing box of suitable size, while the ear of the hearer is placed at the other focus." The working of the two apparatus (the mode of connection of which is visible in the wood-cuts), the transmitter being placed at one station and the receiver at the other, is as follows: By speaking, singing, or the intromission of instrumental sounds into tube *a b*, in consequence of the condensation and rarefaction of the column of air, a motion of the membrane *c* corresponding to these changes is brought about. Lever *c d* follows the motions of the membrane, and opens or closes the circuit, according as a condensation or a rarefaction of the air inside takes place. As a consequence the electro-magnet *m m* (Fig. 505) is correspondingly demagnetized or magnetized, and the armature affixed to it (as well as the armature lever) is set into similar vibrations as the membrane of the transmitter. Through lever *i* connected with the armature, similar vibrations are communicated to the surrounding air and (the increasing effect of the sounding board helping) the tones so produced finally reach the ear of the listener. In respect to the operations of this apparatus, the author remarks that the receiver does reproduce the exact number of the original vibrations, but that a reproduction of the original intensity

has not yet been attained. For that reason, it is added, small differences in the vibrations are appreciated with difficulty, and in the practical experiments made thus far, it was possible to transmit with astonishing faithfulness chords, airs, &c., whilst in reading, speaking, &c., single words were more indistinctly heard. The apparatus just described is said to have been one of the constructions which Reis has used himself in his experiments. The underlying principles might give hopes of a farther improvement of the apparatus, but the telephone which, according to later reports, Reis has finally decided upon, has the disposition represented in Fig. 506, although the principle on which it is founded does not stand quite in harmony with the above-mentioned investigations of Wertheim, for instance.

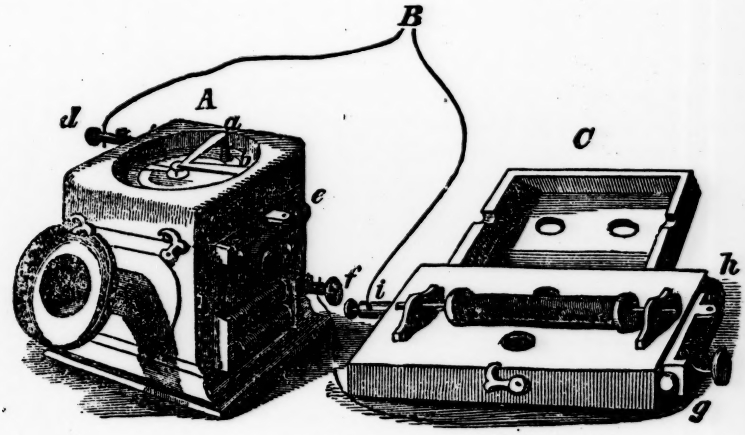


Fig. 506.

The telephone proper A consists of a hollow wooden box provided with a short sound-funnel S, and the upper side of which is open in the centre and covered over tightly with a delicate membrane. On the middle of the latter a thin platinum disc is fastened, from which on one side a platinum strip establishes circuit connection with the contact of the key at *e*, from which place the metallic connection is effected with one end of the coil of a small electro-magnet provided with a spring armature, whilst the other end is in contact with screw *f*. The reproducing apparatus C set up at the receiving station consists simply of a coil about six inches long formed by winding six layers of copper wire; in the axis of the coil a thin iron wire ten inches long (a knitting-needle), protruding out of each end of the coil about two

inches, is so disposed that with its bridge-like supports it rests on a sounding-board. By means of screw *i* and of the key at *h g* the coil is thrown into the circuit and the connection of both apparatus is effected in the manner mentioned; a battery being placed at B, the course of the current is easily followed out. It can flow from B through *d c* and *c b* to *e* and *f*, and from here to the receiving station, and at *i* return to the battery, or it can start in the opposite direction according as *d* or *i* forms the starting point of the current. The circuit can be broken at will at each of the two stations by pressing the key lever, and a connection can be established thus in either direction, but the discontinuous currents which are to produce the sounding of the iron wire at C are obtained in this way: By singing or the blowing of instruments towards the sound-funnel S the membrane at A is made to vibrate; if this can be brought about, it will happen, as was demonstrated by the experiments, that the iron wire of the receiver assumes isochronal vibrations, and whenever this is the case, it reproduces the same tones which set the membrane to vibrating at the transmitting station.

My own experiments have demonstrated that every melody starting from *c* and embracing the entire extent of an average male voice, when sung into the telephone can be reproduced by the receiver at C. The timbre [Klang] or quality of the sounds thus reproduced is not pleasant—they are almost like the sounds of toy trumpets, at times also like the buzz of a fly caught in a spider's web, and the like; yet the experiments of Reis are certainly interesting enough to challenge attention.

A reproduction of the words spoken into the telephone with or without variation of pitch was audible at the receiver only in a corresponding noise [entsprechendes Geräusch], while a discriminate perception of single vocal sounds, syllables, or words could not be had. According to communications made on this subject by Reis, he has succeeded in reproducing the tones of organ-pipes not covered, and those of a piano; in this latter case the transmitter was placed on the sounding-board of the piano.

No. 33. HASSLER'S DESCRIPTION OF REIS.

HASSLER'S *Technical Physics. Vienna, 1866, Vol. I., p. 648.*

The subject of phonotelegraphy will end this chapter. This rests upon a phenomenon first observed by Page, afterwards confirmed by

Mariani, and more exactly studied and experimented upon by Wertheim; that is, that iron, under the influence of alternate magnetizing and demagnetizing by means of a galvanic helix, is set in longitudinal vibration and gives forth sound; and Reis showed beyond doubt the possibility of phonotelegraphy by means of an apparatus called by him telephone (Fig. 429), consisting of two parts—the actual telephone (I), and the reproduction apparatus (II), used at the second station at a distance. Both parts are connected with one another and with a battery *s*, as in ordinary telegraphs. The battery *s* must be strong enough to work the armature *a* of the electro-magnets *e e* (three or four six-inch Bunsen's elements are sufficient for a distance of several hundred feet). The current passes from *s* to the binding screw 2, thence through the strip of copper *n* into the disc of platinum *o*, resting on the middle of a thin circular membrane (hog's gut), stretched across the upper end of the wooden box *k*; afterwards it goes through the foot (platinum point) of the metallic angle *a b c* (this point standing on the disc *o*), into a vertical screw, provided with a small cavity at its upper end containing a drop of mercury, into which there dips from *a a* a platinum point suspended above, while the angle *a b c* rests at *c* on a small metallic pillar, so as to be very easily made to vibrate about *a* and *c*. From this pillar (at *c*) the current goes through the key *t* and into the binding screw *i* connected with the wire leading to the pillar, thence through a wire stretched from this screw into the binding screw 3 on the apparatus 4, then through the key *t* of this apparatus into the bobbin *g* (magnetizing coil), enclosing the iron or steel wire *d d*, of the thickness of a knitting-needle, into the binding screw 4, and finally thence by wire back to the second pole of the battery *s*. If, now, we produce sufficiently strong tones by means of organ-pipes in front of the opening of the tube T (or sing them through the tube T in the hollow box *k*), the waves of the sound set the membrane *m* into regular vibrations. Every condensation occurring beneath *m*, at once raises the disc of platinum *o*, together with the platinum point *b* (the foot of the angle *a b c*); when the rarefaction occurs and *m* moves downward again, the angle *a b c* cannot immediately follow the disc *o*, and the current is interrupted, and a similar interruption occurs with every vibration of *m*, and in this way are produced just as many vibrations in the wire *d d* of the coil *g*, at station II, as the membrane makes; these vibrations are perceived there as tones and combination of tones (accords). These tones are much strengthened by covering the coils with a box of resonant wood *d*, for a sounding-board, so placed as to fit the sounding-board,

b, below. The keys X and X make it possible to communicate short messages as necessity arises, between stations I and II. (*E. g.*, to signify from II to I that they are ready to receive communications at II.) For by pressing down the keys the electro-magnet *e* is included in the circuit, the armature *a* drawn up and made to strike upon *e*.

The telephone is yet in its infancy, it is true, but even now, by employing powerful currents, it transmits at a distance not only solitary tones, but even tunes consisting of slow consecutive tones, quite perceptibly and distinctly.

Third Edition.]

A. D. 1870, *8th April*. N°. 1044.

Electric Telegraphs.

LETTERS PATENT to Cromwell Fleetwood Varley, of Beckenham, in the County of Kent, for the Invention of "IMPROVEMENTS IN ELECTRIC TELEGRAPHS."

PROVISIONAL SPECIFICATION left by the said Cromwell Fleetwood Varley at the Office of the Commissioner of Patents on the 8th April 1870.

CROMWELL FLEETWOOD VARLEY, of Beckenham, in the County of Kent. "IMPROVEMENTS IN ELECTRIC TELEGRAPHS."

[5] This Invention has for its object the increase of the transmitting power of telegraph circuits by enabling more than one operator to signal independent messages at the same time upon one and the same wire to and from independent stations.

In working land lines it is usual to produce the signals by means of the passage [10] of a current of electricity producing magnetic action, as in the Morse or Hughes instruments, or chemical action, as in the Baines machines.

By my Invention I superpose upon the currents used for working the ordinary telegraphs rapid undulations or waves which do not

practically alter the mechanical or chemical power of the ordinary signal currents, and by new apparatus hereinafter [15] described these undulations are made to produce distinct and independent audible or other signals so long as these undulations are produced, whether ordinary signal currents be flowing or not.

As a rough mechanical illustration of the way in which I propose to pass two sets of electric signals simultaneously and in either direction through the same line [20] wire without interference I will suppose a rope stretched over two distant pulleys by means of weights at each end; if the near weight be raised the distant one falls. In this way signals are transmitted by the connecting rope, which may be called current signals; if now two small pulleys capable of rising and falling rest upon the rope between but near to the supports they will simply rotate when the rope is [25] shifted backwards and forwards; if now an operator at one end strike the rope vibrations or waves will be produced which will cause the other small pulley to dance or make vibration signals. Consequently the operator who shifts and the operator who strikes the

[*Price* 8*d.*]

2 A. D. 1870.—N° 1044. Provisional Specification.

Varley's Improvements in Electric Telegraphs.

rope can each produce independent signals on one and the same rope.

Suppose the rope to travel over several fixed pulleys, the operation of shifting the rope will produce distinct current signals from end to end of the line as before, but between each fixed pulley vibrations can be produced, and so a number of [5] intermediate stations can communicate independently of each other and independently of the current signals through the line.

With this mechanical simile the following will be more easily understood.

The way in which I carry my electric Invention into operation is as follows:—

An electro-magnet offers at the first moment great opposition to the passage of a [10] current of electricity, and therefore it may be considered as partially opaque to the transmission of very rapid alternations or electric waves.

I attach to the line at desirable parts condensers. In the first instance I will assume only two condensers, one at each end, attached near each end of an ordinary telegraph line. [15]

The first or communicating station produces in its condenser rapid charges and discharges; these add to and take from the line a number of small electric impulses without affecting the mean magnetizing power of the currents through the line. These impulses charge and discharge the second condenser at the other end. [20]

These undulations in the second condenser can be utilized in the following manner:—

1. If the condenser be made of paper and metal foil the rapid charges and discharges produce a musical sound.

2. If those rapid alternations be made to pass round a helix containing an iron [25] rod a musical sound is produced.

3. If these currents pass round a helix containing a magnetized harmonium tongue the currents make it vibrate audibly if the currents be properly timed, and the effect is increased if a feeble current of air be passing the tongue. By adding tubes of proper length and sounding-boards and other appliances for communicating [30] vibrations the power of the signal is increased.

4. By placing the magnetized tongue of a musical comb between the poles of an electro-magnet with only a small iron core, or inside a coil, it is made to vibrate whenever these undulations are passing.

Another method of producing sound from the undulations consists of stretching a [35] music wire through hollow trelices; the currents magnetize and demagnetize the tone, this wire being also placed between the poles of permanent magnets.

Harmonious currents cause this wire to vibrate. In some cases it may be useful to employ inharmonious currents to stop or silence the vibrations.

The two latter methods will only speak when vibrations or harmony with the [40] tongue are made to pass, and consequently in some cases two or more distinct sets of vibrations can be made to act on two or more sets of apparatus differently tuned, and to permit of several distinct communications to be transmitted simultaneously upon the same section of a single line wire.

By introducing between the receiving condenser and a Morse or other ordinary [45] receiving instrument a current reverser keeping time with the vibrations, these alternating currents are made to flow through the receiving instrument in one direction, and are then competent to work the Morse or other ordinary receiving instrument.

6. When it is desirable to subdivide the vibrating sections of a line an electro-[50] magnet, or, what is better, two electro-magnets are inserted in the circuit, and a condenser may with advantage be placed

between the circuit and the earth connecting the condenser with the circuit between the two electro-magnets.

In this way, without interfering materially with the ordinary signals through the line, the vibrating sections are separated from each other by withdrawing the iron [55] cores from the electro-magnets, or short circuiting the electro-magnets the vibrations are passed through to the next station.

Provisional Specification. A. D. 1870.—N° 1044. 3

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7. Another method consists of inserting a reflecting galvanometer between the condenser and the earth (or between the line and the condenser); the vibratory or secondary signals can be read off by observing its vibrations.

8. Vibrations are rendered sensible by placing a moveable iron bar between the [5] poles of an electro-magnet or inside a helix, and one or both of its ends between the poles of permanent magnets; the latter are covered with brass or any non-magnetic matter; the vibration currents cause it to vibrate between the poles of the electro or permanent magnets, and so produce distinctly audible sounds.

9. There are other methods of utilizing these superposed vibrations, such as [10] connecting to the condenser an electrometer like that of Milner or Pettier. An intermediate Morse or other such line instrument would cut off the vibration signals or reduce them much; this opposition of the intermediate electro-magnet may be cut off by connecting the terminals of a condenser to the circuit on each side of the magnet.

[15] There are several methods of producing these vibrations in the wire :—

1st. If a tuning fork be placed between the poles of an electro-magnet with a spring contact so arranged that when at rest the battery current flows through the electro-magnet the latter will attract the tuning fork and break the circuit; the magnetism then ceases, and the tuning fork springs back and renews the circuit; in [20] this way it keeps vibrating so long as the battery is in action.

A secondary wire around this magnet produces currents in opposite directions, and by placing this secondary wire in circuit with the line wire the necessary vibrations are produced.

2d. The secondary wire may be connected between the earth and the condenser [25] attached to the line wire; this method does not add to the resistance of the main circuit, and is therefore preferable.

3d. A tongue similar to those used in harmoniums is made to vibrate by air between contact points, and so connect the condenser alternately with the battery and the ground, and so produce the alternations, or it may be made to connect the [30] condenser alternately to the + or — pole of a battery whose opposite poles are connected to the earth.

4th. A magneto machine rapidly rotating will do the above duty equally well if its speed of rotation be controlled by a good governor.

The tuning fork and vibrating tongue arrangement can be set to and can keep [35] up any desirable rate of vibrations.

The ordinary telegraph keys and switches are used for connecting the various parts of the apparatus together.

In constructing the dry paper condensers it is best to dip the paper in varnish and attach metal leaf (such as gold, silver, or copper) to the paper, and lay these [40] metal coated papers between metal foil.

The double speaking apparatus of Dr. Gintl, or of Firschen, can be used on lines working with the above described vibrations.

When these are used I prefer inserting a hollow helix between the double speaker and the line, and by inserting iron rods in this helix the difficulty arising [45] from the inductive capacity of the line is almost wholly removed. This is a new improvement, and will render these apparatus actually useful instruments.

R 1444 Wt. 192.

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SPECIFICATION in pursuance of the conditions of the Letters Patent filed by the said Cromwell Fleetwood Varley in the Great Seal Patent Office on the 8th October 1870.

CROMWELL FLEETWOOD VARLEY, of Beckenham, in the County of Kent. "IMPROVEMENTS IN ELECTRIC TELEGRAPHS." [5]

This Invention has for its object the increase of the transmitting power of telegraph circuits by enabling more than one operator to signal independent messages at the same time upon one and the same wire to and from independent stations.

In working land lines it is usual to produce the signals by means of the passage [10] of a current of electricity producing magnetic action,

as in the Morse or Hughes instruments, or chemical action, as in the Baines machines.

By my Invention I superpose upon the currents used for working the ordinary telegraphs rapid undulations or waves which do not practically alter the mechanical or chemical power of the ordinary signal currents, and by new apparatus herein-[15]after described these undulations are made to produce distinct and independent audible or other signals so long as these undulations are produced, whether ordinary signal currents be flowing or not.

As a rough mechanical illustration of the way in which I propose to pass two sets of electric signals simultaneously and in either direction through the same line wire [20] without interference, I will suppose a rope stretched over two distinct pulleys by means of weights at each end. With such an apparatus, if the near weight be raised the distant one falls, and in this way signals may be transmitted by the connecting rope, which may be called current signals. If now two small pulleys capable of rising and falling rest upon the rope between but near to the supports they will [25] simply rotate when the rope is shifted backwards and forwards; but if now an operator at one end strike the rope vibrations or waves will be produced, and will cause the small pulley at the other end to dance, and so vibration signals may be given. Consequently the operator who shifts and the operator who strikes the rope can each produce independent signals on one and the same communicating cord. [30] Suppose the rope to travel over several fixed pulleys the operation of shifting the rope will produce distinct current signals from end to end of the line as before, but between each fixed pulley and the next to it vibrations can be produced, and so a number of intermediate stations can communicate independently of each other, and independently of the current signals through the line. [35]

With this mechanical simile the following will be more easily understood.

The way in which I carry my electric Invention into operation is as follows:—

Condensers are attached to the line at the places where the wave signals are to be communicated and received. In the first place let us assume only two condensers, one at each end, attached near each end of an ordinary Morse telegraph circuit. The [40] first or communicating station to make a signal produces in its condenser rapid charges and discharges by means described; further on these add to and take from the line a number of small electric impulses without affecting the

mean magnetizing power of the ordinary Morse currents through the line. These impulses charge and discharge the second condenser at the other end, and this condenser is coupled with [45] a receiving instrument which is sensitive to these undulations and renders them apparent by sound or otherwise.

Fig. 1 is a diagram of the instruments at one of the stations of such a line; *a* is the line wire, I will suppose it to be an ordinary land line wire 50 miles long and suspended in the usual way; *b* is the Morse instrument, *c* the sending key for [50] the Morse signals, *d* the battery in connection with this key, and *e* its earth connection; *f* is a condenser of about 3 micro farads, one armature of which I couple with the line wire and the other with a key *g*, which when not depressed puts the condenser in communication with the wave signal

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receiving instrument *h*, which I call a "cymaphen;" this instrument is shown at Figs. 2, 3, and 4. The key *g* when depressed for sending a wave signal puts the condenser in connection with the apparatus by which such waves are generated; this apparatus consists of a battery *i*; ten quart cells of Daniel's battery will be suitable.

[5] One pole of the battery *i* is connected with the tuning fork *k*; this fork may conveniently be of such dimensions as to make 200 vibrations in a second. l^1, l^2, are two platina pointed contact making springs, capable of fine adjustment by means of screws. The spring l^1 when the fork is at rest is in metallic contact with it or with a metal arm attached to it, and the spring l^2 is removed just out of [10] contact. The current from the battery *i* then passes in the coils of the electro-magnet *m*, the poles of which have between them the two horns of the tuning fork. The coils of this magnet may be about 3½ inches long, and 1½ inches diameter, and of No. 16 (B.W.G.) silk covered copper wire. When the current is flowing through the coils of the electro-magnet the horns of the fork *k* are drawn [15] apart and the spring l^1 loses its contact; then as the attraction of the magnet ceases the horns of the fork spring back; this re-makes the contact, and so a continual tremor is communicated to the tuning fork. In the same circuit with the electro-magnet there is at *n* a primary coil wound upon a bundle of iron wires as a core, and on the same core but wound in the opposite direction is a second [20] primary coil which is in connection with the spring l^2, so that currents pass alternately in the two primary coils,

and at each alternation the polarity of the core is reversed. On the core there is also another or secondary coil, in which currents are induced by the changes of polarity of the iron core. One end of this secondary coil is connected with the earth, and the other when a wave signal is to [25] be sent is by the key *g* put in connection with the condenser *f*, and produces in it rapid charges and discharges.

The core may conveniently consist of a bundle of thin soft iron wires, 1 inch in diameter and 32 inches long. On the centre of the bundle is wound for a length of eight, the first primary coil consisting of four layers of No. 16 silk covered [30] copper wire. Over this is wound the second primary coil, consisting also of four layers, and outside this again is wound the secondary coil consisting of eight layers of No. 24 silk covered wire. The ends of the bundle composing the core are folded over so as completely to enclose the coils.

A small resistance coil *o*, or a condenser of about two micro farads, is placed [35] between the poles of the secondary coil to take off the violence of the shock, so that the operator shall not be inconvenienced. The wave signal receiving instrument *h* is shown in plan at Fig. 2, in longitudinal section at Fig. 3, and in transverse section at Fig. 4. It consists of an iron frame containing a sounding board *a* over bridges, at the ends of which a hard drawn iron or steel wire *b* is [40] stretched from one end to the other; this wire is about four feet and six inches long between the bridges; it is of No. 14 gauge, and is strained so as to sound the same note as the tuning fork of the sending instrument. This wire passes through a hollow helix *c*, three inches in length, $\frac{1}{6}$ of an inch internal diameter and 1½ inches external diameter. The helix is wound with No. 35 B. W. G. copper wire insulated [45] with silk. This coil is attached to the frame supporting the sounding board, but does not touch the latter. Two horse-shoe magnets *d* are placed one on each side of the wire. The currents magnetize the wire inside the helix, and so cause it to be attracted and repelled from one magnet to the other. When the wire is properly tuned so as to vibrate synchronously with the apparatus at the distant end making [50] the alternations in the current the sound from very feeble currents is distinctly audible. A piece of felt or leather resting against the wire is sometimes used to "damp" the wire and stop its vibrations as soon as the impulses cease.

A small piece of metal similar in dimensions to a gold five franc piece may be made to rest by a spring lightly against the sounding board somewhere near its [55] centre. When the vibrations of the latter are powerful enough to make this piece of metal dance, the sound is

increased in power four or five times by this little disc or sound reinforcer, or the sound may be augmented by clipping on to the wire

near the helix a disc of about the size of a penny piece of thin sheet metal; this causes the vibration of the wire to produce a greater disturbance in the air than it otherwise would, and a louder sound is perceived.

By attaching a stethescope to the sounding board for the reader to rest his ear against very feeble sounds are rendered sufficiently audible; I prefer to use a [5] Scott Allison's stethescope.

The sounding board may be replaced by a *strained diaphragm or drum-head*, on which one of the bridges over which the wire is strained is supported; this arrangement gives a better sound with very feeble currents, but with moderate currents the sounding board appears to have the advantage. [10]

Two sets of wave signals may be transmitted and received simultaneously through the same wire, and independently of the current signals if a sufficient difference be made in the periods of the two sets of waves. Thus, if waves of 200 vibrations in the second, and waves 850 or 900 vibrations in the second, be simultaneously transmitted and received by two separate cymaphens, the one adjusted to [15] the slow, and the other to the rapid vibrations, they may be separately read, as the vibrations which affect the one are inoperative on the other. This arrangement is not applicable when working long distances, as rapid waves would in a long distance be lost.

Fig. 5 is a diagram illustrating the arrangements I make when the wave [20] signals are used to communicate between intermediate or branch stations without interfering with the working by ordinary instruments of the main line; *a* is the line wire, say between London and Southampton, and through it it is desired that the intermediate station, Basingstoke, shall without interference with the through messages be able to communicate to and fro with the branch stations, Windsor and [25] Salisbury. At these branch stations I provide wave signal apparatus such as already described in respect to Fig. 1, coupled with condensers b^1, b^2, at the places where the branches run into the main line. At the intermediate station, Basingstoke, I divide the line wire into two sections (as far as the wave signals are concerned), by introducing at *c* an instrument which is opaque to these waves, whilst

Vibrations are rendered sensible by placing a moveable iron bar between the poles of an electro-magnet or inside a helix, and one or both of its ends between the poles [40] of permanent magnets; the latter are covered with brass or any non-magnetic matter. The vibration currents cause it to vibrate between the poles of the electro or permanent magnets, and so produce distinctly audible sounds. Another method of utilizing these alternations is by introducing between the receiving condenser and a Morse or other ordinary receiving instrument a current reverser keeping [45] time with the vibrations; these alternating currents may be made to flow through the receiving instrument in one direction, and are then competent to work the Morse or other ordinary receiving instrument. Or a similar result may be obtained by the arrangement shown at Fig. 6, which consists in connecting the receiving condenser to two "Geisler's" vacuum tubes *a* and *b*; the latter are connected with [50] voltaic batteries C, Z, consisting of a large number of elements. The one tube *a* is connected to the "positive "pole" of a battery whose "negative pole" is connected to the earth. The second tube *b* is connected to the "negative pole" of a battery whose "positive pole" is to earth. These batteries must have nearly power enough to make a current pass through the tubes; for example, supposing three hundred [55] cells of a battery be able to leap across the exhausted tube, 290 should be used with each tube. When a positive current arrives it will help the battery whose positive pole is connected to the earth, and cause a current to pass through its tube *b*.

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The next instant the current is reversed; this causes a current to pass through the other tube *a*; in this way an electric valve is produced separating the positive from the negative currents, and producing a rapidly intermittent current in one direction only. If a reflecting galvanometer be enclosed in the circuit formed by the batteries and the tubes the wave signals will be indicated by it. [5]

Another method of producing an electric valve for separating the positive from the negative currents is illustrated by Fig. 7, and consists in connecting, say 5 cells of Daniel's battery with 3 cups containing dilute sulphuric acid with platinum plates joined up so as to form 3 decomposition cells in series. Between the battery and the 3 cups is inserted the galvanometer or other instrument that is to be [10] worked; the junction between the instrument and the cups or decom-

position cells is connected to the condenser. The other junction between the battery and the decomposition cells is connected to the earth. The first action of the battery is to polarize the platinum plates when the current almost entirely ceases, the three pairs of polarized platinum plates balancing the 5 Daniel's cells. The moment a [15] current arrives from the condenser it finds two channels open to the earth —the one the battery, the other the decomposition cells. Suppose the positive pole of the battery to be in connection with the earth and a positive current arriving from the condenser, at first it divides itself, part going through the battery, part through the decomposition cells. The action of the current upon the latter is to depolarize [20] them, and they then immediately resist its flow.

The next moment a negative current flows from the condenser; this negative current is assisted by the partly depolarized plates, and the battery and the former become repolarized. It is best to wrap the instrument, as the diagram shows, with two wires connecting the one with the cups, the other wire with the battery, and [25] their junction with the condenser.

The result is that whether it be a negative or positive current that is sent into this arrangement, the action upon the instrument is the same, and thus out of alternating currents a continuous action is produced.

The platinum plates for this purpose must be very small and very close together, [30] to reduce as much as possible their inductive capacity and resistance.

Another method consists of inserting a reflecting galvanometer between the condenser and the earth (or between the line and the condenser); the vibratory or secondary signals can be read off by observing its tremor. The mirror of this galvanometer must be deadened by water or other damper, and it is best to produce [35] the signals by interrupting the vibrations instead of the reverse. The vibrations keep the mirror oscillating, the image becomes spread out, and the light enfeebled. The moment the vibrations are cut off the light contracts. The effect is the "spread out" light is feeble, the "concentrated" is bright, and thus the signals can be flashed by long and short duration like the Morse alphabet. [40]

Another method of utilizing these superposed vibrations is to connect to the condenser an electrometer like that of Milner or Pettier. A resistance coil of about 1000 ohms is connected between the condenser and the earth as a shunt to the electrometer to prevent the Morse signals from affecting it to any sensible extent; or the wave signals may be read by the sense of touch. For this purpose [45] I use a handle

made of hard charcoal, and divided into two parts longitudinally. The parts are separated by a sheet of gutta percha, and are connected, the one with the armature of the condenser, the other with the earth. The handle being moistened and covered with a rag wetted with weak salt and water, is firmly grasped in the hand. [50]

An intermediate Morse or other such line instrument would cut off the vibration signals or reduce them too much; this opposition or opacity of the intermediate instrument is destroyed by connecting the terminals of a condenser to the circuit on each side of the magnet. Thus, if I wish wave signals to pass a Morse instrument I couple the armatures of a condenser of 3 to 10 microfarads with the line [55] wire, one on either side of the Morse instrument. The working of the Morse line, if there are many instruments in circuit, is also in this way improved.

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There are several methods of producing electric waves in the lines in addition to that already described.

A tongue similar to those used in harmoniums is made to vibrate by air between contact points, and so connect the condenser alternately with the battery and the [5] ground, and so produce the alternations, or it may be made to connect the condenser alternately to the + or — pole of a battery whose opposite poles are connected to the earth.

A magneto machine, rapidly rotating, will do the above duty equally well if its speed of rotation be controlled by a good governor.

[10] The double speaking apparatus of Dr. Gintl, or of Frischen, can be used on lines working with the above described vibrations.

Fig. 8 is a diagram of this arrangement. *a* is the line wire; *b*, *b*, the condensers; *c*, *c*, the cymaphens, wave signal transmitters, and parts connected therewith; *d*, *d*, are the current signal keys and batteries; and *e*, *e*, are the magnets [15] of Dr. Gintl or Frischen's receiving instruments; and *f*, *f*, are their resistance coils. I prefer wrapping the magnets *e*, *e*, with three or four wires, using one wire between the key and the earth through its resistance coil, and the two or three wires joined into one circuit attached to the line wire. I insert a hollow helix between the double speaker and the line, and by putting iron rods in this helix the difficulty [20] arising from the inductive capacity of the line is almost wholly removed; this is a new improvement and will

render these apparatus actually useful instruments. The helix may conveniently be of No. 26 silk covered wire and 10 inches long, with a diameter inside of 1½ inches, and outside of 4 inches; small iron rods are placed in this helix one by one until it is found that the finger key does not affect [25] the indicator of the home receiving instrument. By using these instruments, these apparatus together with cymaphens, as is shown in Fig. 8, three messages can be sent from end to end of such a circuit at the same time independently of each other; for this purpose the cymaphen key must have a spring contact so that the circuit between the condenser and the earth is never broken until the contact with [30] the secondary coil is complete.

I would remark that in electric telegraphs the use of sound signals is not claimed by me and is not new; for example, in working step by step instruments in which a pointer should indicate the desired letter on a dial, it has been common when the instrument is out of order and fails to indicate correctly to give sound signals; by [35] its means such sound signals are read according to the Morse alphabet, a short sound such as the escapement of the receiving instrument makes when moving a few steps only representing a dot, and a long sound such as the escapement makes when moving over many steps representing a dash.

Having thus described the nature of my Invention, and the manner of performing [40] the same, I would have it understood that I claim the construction of electric telegraphs in such manner that current signals and wave signals may be simultaneously transmitted through the same line wire, and may be rendered sensible at the receiving station by separate instruments, the one sensitive to currents of appreciable duration and the other *to electric waves or vibrations.*

[45] I also claim the construction of electric telegraphs with, at the transmitting station, an instrument capable of originating in the line wire a succession of rapid and *regular electric waves*, and at the receiving station a strained wire, a tongue, or such like instrument adjusted to vibrate in unison with the electric waves, and being magnetized by them oscillating to and from the pole or poles of a magnet in its [50] vicinity.

I also claim in the construction of electric telegraphs the dividing a conducting wire into sections by instruments which I have called "echocyme," which allow current signals to pass freely but stop wave signals, so that whilst the wire is being used as a whole for through signals the sections into which it is divided may each [55] or all be employed for the transmission of local messages.

I also claim the construction of electric telegraphs with, at the transmitting station, an instrument capable of originating in the line wire a succession of rapid and *regular electric waves*, and at the receiving station a condenser, consisting of thin sheets, capable of being agitated by such waves.

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I also claim the construction of electric telegraphs with, at the transmitting station, an instrument capable of originating in the line wire a succession of rapid and regular electric waves, and at the receiving station an instrument which on [5] receiving such waves delivers a current of electricity to an indicating or receiving instrument suitable to be worked with ordinary current signals.

I also claim the combination with Dr. Gintl and Frischen's double speaking apparatus of a hollow helix connected between the receiving instrument and the line wire, such helix having rods or pieces of iron inserted into it. [10]

In witness whereof, I, the said Cromwell Fleetwood Varley, have hereunto set my hand and seal, this Seventh day of October, in the year of our Lord One thousand eight hundred and seventy.

CROMWELL F. VARLEY. (L. S.)

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For Her Majesty's Stationery Office.

[192.—50.—4/82.]

EXTRACTS OF PROCEEDINGS OF THE SOCIETY OF TELEGRAPH ENGINEERS.

Special General Meeting, held at 25 Great George Street, Westminster, on Wednesday, the 31st October, 1877. PROFESSOR ABEL, C. B., F. R. S., President, in the Chair.

The PRESIDENT:—Gentlemen, the Council of the Society of Telegraph Engineers felt that they were sure of doing what the members would consider right in summoning a special meeting for the two-fold purpose of giving a welcome to Professor Bell to this country and affording the members an opportunity of hearing from him an account, which he has been so good as to promise to give us, of the nature, history, and development of, what may well be called, one of the most interesting discoveries of our age. Our time is very precious this evening. We all desire to hear everything Professor Bell can tell us on this subject, and many gentlemen will probably desire afterwards to ask questions or discuss the subject, for I see present a great number of eminent scientific men. I will not waste another moment, but at once call upon Professor Bell to commence his discourse on the Electric Telephone.

RESEARCHES IN ELECTRIC TELEPHONY.

BY PROFESSOR ALEXANDER GRAHAM BELL.

PROFESSOR BELL:—Mr. President and Gentlemen of the Society of Telegraph Engineers. It is to-night my pleasure, as well as duty, to give you some account of the telephonic researches in which I have been so long engaged. Many years ago my attention was directed to the mechanism of speech by my father, Alexander Melville Bell, of Edinburgh, who has made a life-long study of the subject. Many of those present may recollect the invention by my father of a means of representing, in a wonderfully accurate manner, the positions of the vocal organs in forming sounds. Together we carried on quite a number of experiments, seeking to discover the correct mechanism of English and foreign elements of speech, and I remember especially ar

investigation in which we were engaged concerning the musical relations of vowel sounds. When vowel sounds are whispered, each vowel seems to possess a particular pitch of its own, and by whispering certain vowels in succession a musical scale can be distinctly perceived. Our aim was to determine the natural pitch of each vowel; but unexpected difficulties made their appearance, for many of the vowels seemed to possess a double pitch—one due, probably, to the resonance of the air in the mouth, and the other to the resonance of the air contained in the cavity behind the tongue, comprehending the pharynx and larynx.

I hit upon an expedient for determining the pitch which at that time I thought to be original with myself. It consisted in vibrating a tuning-fork in front of the mouth while the positions of the vocal organs for the various vowel sounds were silently taken. It was found that each vowel position caused the reinforcement of some particular fork or forks.

I wrote an account of these researches to Mr. Alex. J. Ellis, of London, whom I have very great pleasure in seeing here to-night. In reply he informed me that the experiments related had already been performed by Helmholtz, and in a much more perfect manner than I had done. Indeed, he said that Helmholtz had not only analyzed the vowel sounds into their constituent musical elements, but had actually performed the synthesis of them.

He had succeeded in producing, artifically, certain of the vowel sounds by causing tuning-forks of different pitch to vibrate simultaneously by means of an electric current. Mr. Ellis was kind enough to grant me an interview for the purpose of explaining the apparatus employed by Helmholtz in producing these extraordinary effects, and I spent the greater part of a delightful day with him in investigating the subject. At that time, however, I was too slightly acquainted with the laws of electricity fully to understand the explanations given; but the interview had the effect of arousing my interest in the subjects of sound and electricity, and I did not rest until I had obtained possession of a copy of Helmholtz' great work,* and had attempted, in a crude and imperfect manner it is true, to reproduce his results. While reflecting upon the possibilities of the production of sound by electrical means, it struck me that the principle of vibrating a tuning-fork by the intermittent attraction of an electro-magnet might be applied to the electrical production of music.

* Helmholtz. *Die Lehre von dem Tonempfindungen.* (English Translation by Alexander J. Ellis, *Theory of Tone.*)

I imagined to myself a series of tuning-forks of different pitches, arranged to vibrate automatically in the manner shown by Helmholtz, each fork interrupting at every vibration a voltaic current; and the thought occurred, "Why should not the depression of a key like "that of a piano direct the interrupted current from any one of "these forks, through a telegraph wire, to a series of electro-mag- "nets operating the strings of a piano or other musical instrument, in "which case a person might play the tuning-fork piano in one place "and the music be audible from the electro-magnetic piano in a distant "city?"

The more I reflected upon this arrangement the more feasible did it seem to me; indeed, I saw no reason why the depression of a number of keys at the tuning-fork end of the circuit should not be followed by the audible production of a full chord from the piano in the distant city, each tuning-fork affecting at the receiving end that string of the piano with which it was in unison. At this time the interest which I felt in electricity led me to study the various systems of telegraphy in use in this country and in America. I was much struck with the simplicity of the Morse alphabet, and with the fact that it could be read by sound. Instead of having the dots and dashes recorded upon paper, the operators were in the habit of observing the duration of the click of the instruments, and in this way were enabled to distinguish by ear the various signals.

It struck me that in a similar manner the duration of a musical note might be made to represent the dot or dash of the telegraph code, so that a person might operate one of the keys of the tuning-fork piano referred to above, and the duration of the sound proceeding from the corresponding string of the distant piano be observed by an operator stationed there. It seemed to me that in this way a number of distinct telegraph messages might be sent simultaneously from the tuning-fork piano to the other end of the circuit, by operators each manipulating a different key of the instrument. These messages would be read by operators stationed at the distant piano, each receiving operator listening for signals of a certain definite pitch, and ignoring all others. In this way could be accomplished the simultaneous transmission of a number of telegraphi messages along a single wire, the number being limited only by ti. delicacy of the listener's ear. The idea of increasing the carrying power of a telegraph wire in this way took complete possession of my mind, and it was this practical end that

I had in view when I commenced my researches in Electric Telephony.

In the progress of science it is universally found that complexity leads to simplicity, and in narrating the history of scientific research it is often advisable to begin at the end.

In glancing back over my own researches I find it necessary to designate, by distinct names, a variety of electrical currents by means of which sounds can be produced, and I shall direct your attention to several distinct species of what may be termed "telephonic" currents of electricity. In order that the peculiarities of these currents may be clearly understood, I shall ask Mr. Frost to project upon the screen a graphical illustration of the different varieties.

The graphical method of representing electrical currents here shown is the best means I have been able to devise of studying in an accurate manner the effects produced by various forms of telephonic apparatus, and it has led me to the conception of that peculiar species of telephonic current here designated as *undulatory*, which has rendered feasible the artificial production of articulate speech by electrical means.

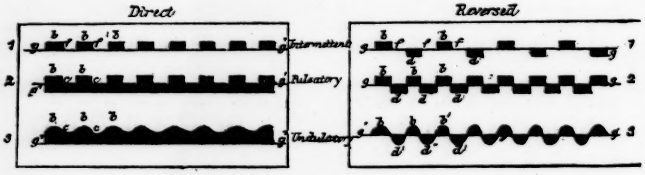

Fig. 1.

A horizontal line ($g\ g'$) is taken as the zero of current, and impulses of positive electricity are represented above the zero line, and negative impulses below it, or *vice versâ*.

The vertical thickness of any electrical impulse (b or d), measured from the zero line, indicates the intensity of the electrical current at the point observed, and the horizontal extension of the electric line (b or d) indicates the duration of the impulse.

Nine varieties of telephonic currents may be distinguished, but it will only be necessary to show you six of these. The three primary varieties designated as "intermittent," "pulsatory," and "undulatory," are represented in lines 1, 2, and 3.

Sub-varieties of these can be distinguished as "direct" or "re-

"versed" currents according as the electrical impulses are all of one kind or are alternately positive and negative. "Direct" currents may still further be distinguished as "positive" or "negative," according as the impulses are of one kind or of the other.

An intermittent current is characterized by the alternate presence and absence of electricity upon the circuit;

A pulsatory current results from sudden or instantaneous changes in the intensity of a continuous current; and

An undulatory current is a current of electricity, the intensity of which varies in a manner proportional to the velocity of the motion of a particle of air during the production of a sound: thus the curve representing graphically the undulatory current for a simple musical tone is the curve expressive of a simple pendulous vibration—that is, a sinusoidal curve.

Telephonic currents of electricity may be

Intermittent	Direct	Positive	1	Positive intermittent current.	
		Negative	2	Negative	" "
	——	Reversed	3	Reversed	" "
Pulsatory	Direct	Positive	4	Positive pulsatory current.	
		Negative	5	Negative	" "
	——	Reversed	6	Reversed	" "
Undulatory	Direct	Positive	7	Positive undulatory current.	
		Negative	8	Negative	" "
	——	Reversed	9	Reversed	" "

And here I may remark, that, although the conception of the undulatory current of electricity is entirely original with myself, methods of producing sound by means of intermittent and pulsatory currents have long been known. For instance, it was long since discovered that an electro-magnet gives forth a decided sound when it is suddenly magnetized or demagnetized. When the circuit upon which it is placed is rapidly made and broken, a succession of explosive noises proceeds from the magnet. These sounds produce upon the ear the effect of a musical note when the current is interrupted a sufficient number of times per second. The discovery of "Galvanic "Music," by Page,* in 1837, led inquirers in different parts of the world

* *C. G. Page.* "The Production of Galvanic Music." Silliman's Journ. 1837, xxxii. p. 396; Silliman's Journ. July, 1837, p. 354; Silliman's Journ. 1838, xxxiii. p. 118; Bibl. Univ. (new series), 1839, ii. p. 398.

almost simultaneously to enter into the field of telephonic research; and the acoustical effects produced by magnetization were carefully studied by Marrian,* Beatson,† Gassiot,‡ De la Rive,§ Matteucci,‖ Guillemin,¶ Wertheim,** Wartmann,†† Janniar,‡‡ Joule,§§ Laborde,‖‖ Legat,¶¶ Reis,*** Poggendorf,††† Du Moncel,‡‡‡ Delezenne,§§§ and others.‖‖‖‖ It should also be mentioned that Gore¶¶¶obtained loud musical notes from mercury, accompanied by singularly beautiful crispations of the surface during the course of experiments in electrolysis; Page**** produced musical tones from Trevelyan's bars by the action of the

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* *J. P. Marrian.* Phil. Mag. xxv. p. 382; Inst. 1845, p. 20; Arch. de l'Électr. v. p. 195.

† *W. Beatson.* Arch. de l'Électr. v. p. 197; Arch. de Sc. Phys. et Nat. (2d series), ii. p, 113.

‡ *Gassiot.* See "Treatise on Electricity," by De la Rive, i. p. 300.

§ *De la Rive.* Treatise on Electricity, i. p. 300; Phil. Mag. xxxv. p. 422; Arch. de l'Électr. v. p. 200; Inst. 1846, p. 83; Comptes Rendus, xx. p. 1287; Comp. Rend. xxii. p. 432; Pogg. Ann. lxxvi. p. 637; Ann. de Chim. et de Phys. xxvi. p. 158.

‖ *Matteucci.* Inst. 1845, p. 315; Arch. de l'Électr. v. 389.

¶ *Guillemin.* Comp. Rend. xxii. p. 264; Inst. 1846, p. 30; Arch. d. Sc. Phys. (2d series), i. p. 191.

** *G. Wertheim.* Comp. Rend. xxii. pp. 336, 544; Inst. 1846, pp. 65, 100; Pogg. Ann. lxviii. p. 140; Comp. Rend. xxvi. p. 505; Inst. 1848, p. 142; Ann. de Chim. et de Phys. xxiii. p. 302; Arch. d. Sc. Phys. et Nat. viii. p. 206; Pogg. Ann. lxxvii. p. 43; Berl. Ber. iv. p. 121.

†† *Elie Wartmann.* Comp. Rend. xxii. p. 544; Phil. Mag. (3d series), xxviii. p. 544; Arch. d. Sc. Phys. et Nat. (2d series), i. p. 419; Inst. 1846, p. 290; Monatscher. d. Berl. Akad. 1846, p.111.

‡‡ *Janniar.* Comp. Rend. xxiii. p. 319; Inst. 1846, p. 269; Arch. d. Sc. Phys. et Nat. (2d series), ii. p. 394.

§§ *J. P. Joule.* Phil. Mag. xxv. pp. 76, 225; Berl. Ber. iii. p. 489.

‖‖ *Laborde.* Comp. Rend. l. p. 692; Cosmos, xvii. p. 514.

¶¶ *Legat.* Brix Z. S. ix. p. 125.

*** *Reis.* "Téléphonie." Polytechnic Journ. clxviii. p. 185; Böttger's Notizbl. 1863, No. 6.

††† *J. C. Poggendorff.* Pogg. Ann. xcviii. p. 192; Berliner Monatsber. 1856, p. 133; Cosmos, ix. p. 49; Berl. Ber. xii. p. 241; Pogg. Ann. lxxxvii. p. 139.

‡‡‡ *Du Moncel.* Exposé, ii. p. 125; also, iii. p. 83.

§§§ *Delezenne.* "Sound produced by Magnetization," Bibl. Univ. (new series), 1841, xvi. p. 406.

‖‖‖‖ See London Journ. xxxii. p. 402; Polytechnic Journ. cx. p. 16; Cosmos, iv. p. 43; Glösener——Traité général, &c., p. 350; Dove.-Repert. vi. p. 58; Pogg. Ann. xliii. p. 411; Berl. Ber. i. p. 144; Arch. d. Sc. Phys. et Nat. xvi. p. 406; Kuhn's Encyclopædia der Physik, pp. 1014-1021.

¶¶¶ *Gore.* Proceedings of Royal Society, xii. p, 217.

**** *C. G. Page.* "Vibration of Trevelyan's bars by the galvanic current." Silliman's Journal, 1850, ix. pp. 105-108.

galvanic current; and further it was discovered by Sullivan* that a current of electricity is generated by the vibration of a wire composed partly of one metal and partly of another. The current was produced so long as the wire emitted a musical note, but stopped immediately upon the cessation of the sound.

For several years my attention was almost exclusively directed to the production of an instrument for making and breaking a voltaic circuit with extreme rapidity, to take the place of the transmitting tuning-fork used in Helmholtz' researches. I will not trouble you with the description of all the various forms of apparatus that were devised, but will merely direct your attention to one of the best of them, shown

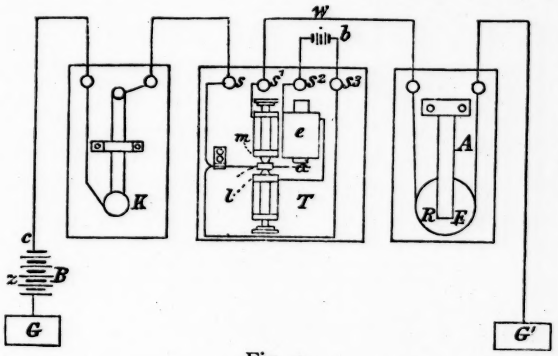

Fig. 2.

in Fig. 2. In the transmitting instrument T, a steel reed *a* is employed, which is kept in continuous vibration by the action of an electro-magnet *e* and local battery. In the course of its vibration the reed strikes alternately against two fixed points *m*, *l*, and thus completes alternately a local and a main circuit. When the key K is depresssed an intermittent current from the main battery B is directed to the line wire W, and passes through the electro-magnet E of a receiving instrument R at the distant end of the circuit, and thence to the ground G. The steel reed A is placed in front of the receiving magnet, and when its normal rate of vibration is the same as the reed of the transmitting instrument it is thrown into powerful vibration, emitting a musical tone of a similar pitch to that produced by the reed of the transmitting instrument, but if it is normally of a different pitch it remains silent.

* *Sullivan.* "Currents of Electricity produced by the vibration of Metals." Phil. Mag. 1845, p. 261; Arch. de l'Électr. x. p. 480.

A glance at Figs. 3, 4, and 5 will show the arrangement of such instruments upon a telegraphic circuit, designed to enable a number of telegraphic dispatches to be transmitted simultaneously

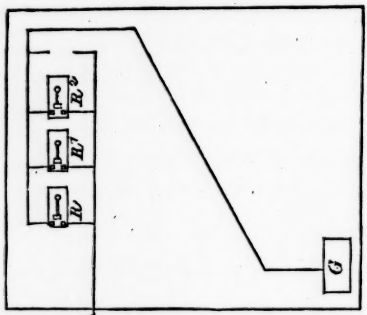

Fig. 5.

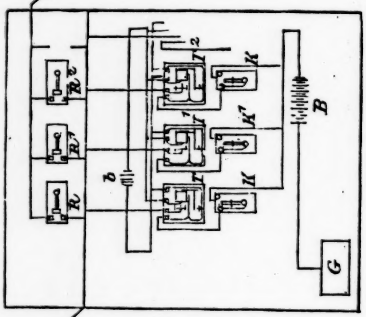

Fig. 4.

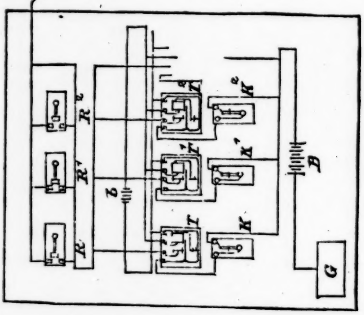

Fig. 3.

along the same wire. The transmitters and receivers that are numbered alike have the same pitch or rate of vibration. Thus the reed of T′ is in unison with the reeds T′ and R′ at all the stations upon the

circuit, so that a telegraphic dispatch sent by the manipulation of the key K′ at the station shown in Fig. 3 will be received upon the receiving instruments K′ at all the other stations upon the circuit. Without going into details, I shall merely say that the great defects of this plan of multiple telegraphy were found to consist, firstly, in the fact that the receiving operators were required to possess a good musical ear in order to discriminate the signals; and secondly, that the signals could only pass in one direction along the line (so that two wires would be necessary in order to complete communication in both directions). The first objection was got over by employing the device which I term a "vibratory circuit-breaker," shown in the next diagram, whereby musical signals can be automatically recorded.

Fig. 6 shows a receiving instrument R, with a vibratory circuit-breaker *v* attached. The light spring-lever *v* overlaps the free end of the steel reed A, and normally closes a local circuit, in which may be placed a Morse sounder or other telegraphic apparatus. When the reed A is thrown into vibration by the passage of a musical signal, the spring arm *v* is thrown upwards, opening the local circuit at the point 5. When the spring-arm *v* is so arranged as to have normally a

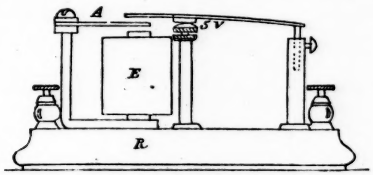

Fig. 6.

much slower rate of vibration than the reed A_1, the local circuit is found to remain permanently open during the vibration of A, the spring-arm *v* coming into contact with the point 5 only upon the cessation of the receiver's vibration. Thus the signals produced by the vibration of the reed A are reproduced upon an ordinary telegraphic instrument in the local circuit.

Fig. 7 shows the application of electric telephony to autographic telegraphy.

T, T′, &c., represent the reeds of transmitting instruments of different pitch, R, R′, &c., the receivers at the distant station of corresponding pitch, and, *r*, *r*′, &c., the vibratory circuit-breakers attached to the receiving instruments, and connected with metallic bristles, 21, resting upon chemically prepared paper P. The message, or picture, to be copied, is written upon a metallic surface, F*o*, with non-metallic

ink and placed upon a metallic cylinder 7, connected with the main battery B; and the chemically prepared paper P, upon which the message is to be received, is placed upon a metallic cylinder connected with the local battery B′ at the receiving station. When the cylinders at either end of the circuit are rotated in the direction of the arrows—but not necessarily at the same rate of speed—a *fac simile* of whatever is written or drawn upon the metallic surface F*o* appears upon the chemically prepared paper P.

The method by means of which the musical signals may be sent simultaneously in both directions along the same circuit is shown in our next illustration, Figs. 8, 9, and 10. The arrangement is

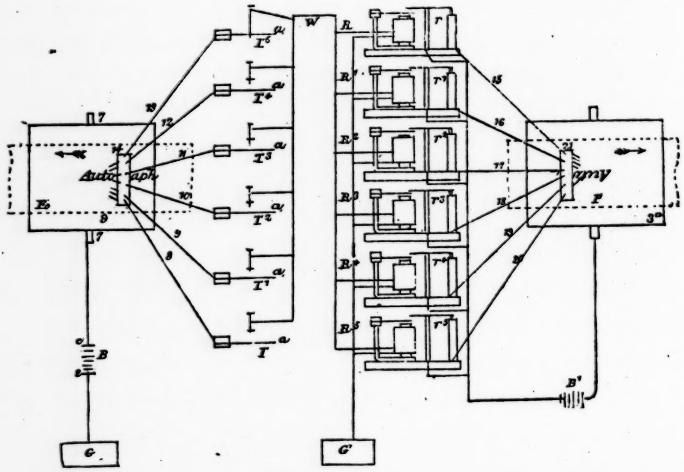

Fig. 7.

similar to that shown in Figs. 3, 4, and 5, excepting that the intermittent current from the transmitting instruments is passed through the primary wires of an induction coil, and the receiving instruments are placed in circuit with the secondary wire. In this way free earth communication is secured at either end of the circuit, and the musical signals produced by the manipulation of any key are received at all the stations upon the line. The great objection to this plan is the extreme complication of the parts and the necessity of employing local and main batteries at every station. It was also found by practical experiment that it was difficult, if not impossible, upon either of the plans here shown, to transmit simultaneously the number of mu-

sical tones that theory showed to be feasible. Mature consideration revealed the fact that this difficulty lay in the nature of the electrical current employed, and was finally obviated by the invention of the *undulatory* current.

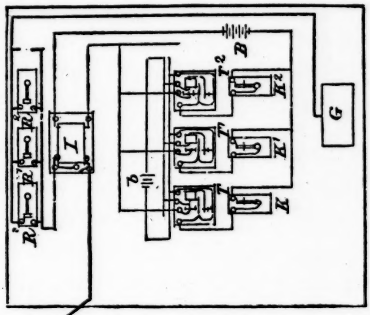

Fig. 10.

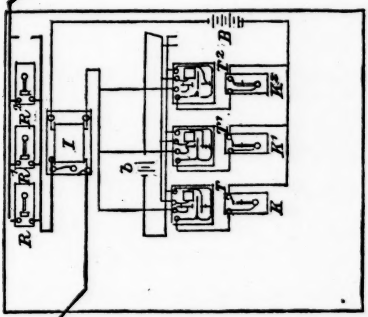

Fig. 9.

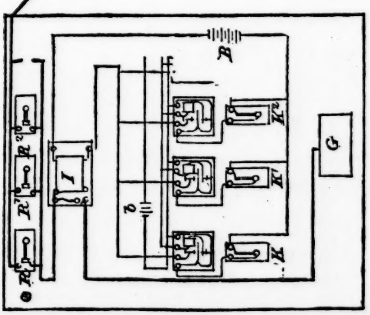

Fig. 8.

It is a strange fact that important inventions are often made almost simultaneously by different persons in different parts of the world,

and the idea of multiple telegraphy as developed in the preceding diagrams seems to have occurred independently to no less than four other inventors in America and Europe. Even the details of the arrangements upon circuit—shown in Figs. 3, 4, 5, and 8, 9, 10—are extremely similar in the plans proposed by Mr. Cromwell Varley of London, Mr. Elisha Gray of Chicago, Mr. Paul La Cour of Copenhagen, and Mr. Thomas Edison of Newark, New Jersey. Into the question of priority of invention, of course, it is not my intention to go to-night.

That the difficulty in the use of an intermittent current may be more clearly understood, I shall ask you to accompany me in my explanation of the effect produced when two musical signals of different pitch are simultaneously directed along the same circuit. Fig. 11 shows an arrangement whereby the reeds *a* *a'* of two transmitting instruments are caused to interrupt the current from the same battery, B. We shall suppose the musical interval between the two reeds to be a major third, in which case their vibrations are in the ratio of 4 to 5, *i. e.*, 4 vibrations of *a* are made in the same time as 5 vibrations of *a'*. A^2 and B^2 represent the in-

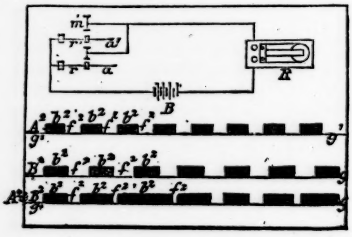

Fig. 11.

termittent currents produced, 4 impulses of B^2 being made in the same time as 5 impulses of A^2. The line $A^2 + B^2$ represents the resultant effect upon the main line when the reeds *a* and a^1 are simultaneously caused to make and break the same circuit, and from the illustration you will perceive that the resultant current, whilst retaining a uniform intensity, is less interrupted when both reeds are in operation than when one alone is employed. By carrying your thoughts still further you will understand that when a large number of reeds of different pitch or of different rates of vibration are simultaneously making and breaking the same circuit the resultant effect upon the main line is practically equivalent to one continuous current.

It will also be understood that the maximum number of musical signals that can be simultaneously directed along a single wire without conflict depends very much upon the ratio which the "make" bears to the "break;" the shorter the contact made, and the longer the break, the greater the number of signals that can be transmitted without confusion, and *vice versâ*. The apparatus by means of which this theoretical conclusion has been verified is here to-night, and consists of an ordinary parlor harmonium, the reeds of which are operated by wind in the usual manner. In front of each reed is arranged a metal screw, against which the reed strikes in the course of its vibration. By adjusting the screw the duration of the contact can be made long or short. The reeds are connected with one pole of a battery, and the screws against which they strike communicate with the line wire, so that intermittent impulses from the battery are transmitted along the line wire during the vibration of the reeds.

We now proceed to the next illustration. Without entering into

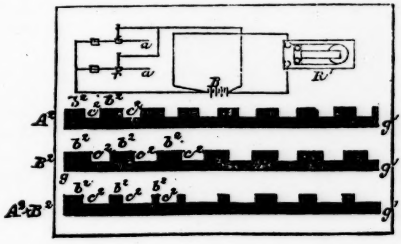

Fig. 12.

the details of the calculation you will see that with a pulsatory current the effect of transmitting musical signals simultaneously is nearly equivalent to a continuous current of minimum intensity—see $A^2 + B^2$,

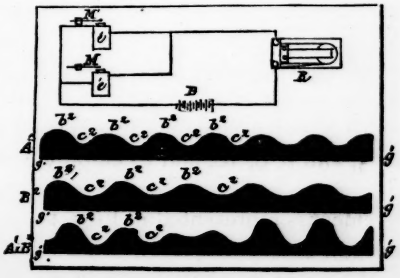

Fig. 13.

Fig. 12; but when undulatory currents are employed the effect is different—see Fig. 13. The current from the battery B is thrown into waves by the inductive action of iron or steel reeds M M′, vibrated in front of electro-magnets *e e′*, placed in circuit with the battery; A^2 and B^2 represent the undulations caused in the current by the vibration of the magnetized bodies, and it will be seen that there are four undulations of B^2 in the same time as five undulations of A^2. The resultant effect upon the main line is expressed by the curve $A^2 + B^2$, which is the algebraical sum of the sinusoidal curves A^2 and B^2. A similar effect is produced when reversed undulatory currents are employed as shown in Fig. 14, where the current is produced by the vibration of permanent magnets M M′ in front of electro-magnets (*e e′*), united upon a circuit without a voltaic battery. It will be understood from Figs. 13 and 14 that the effect of transmitting

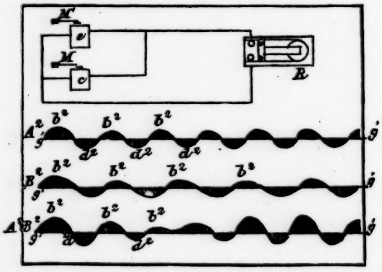

Fig. 14.

musical signals of different pitches simultaneously along a single wire is not to obliterate the vibratory character of the current as in the case of intermittent and pulsatory currents, but to change the shapes of the electrical undulations. In fact, the effect produced upon the current is precisely analogous to the effect produced in the air by the vibration of the inducing bodies M M′. Hence it should be possible to transmit as many musical tones simultaneously through a telegraph wire as through the air. The possibility of using undulatory currents for the purposes of multiple telegraphy enabled me to dispense entirely with the complicated arrangements of the circuit shown in Figs. 3, 4, 5, and 8, 9, 10, and to employ a single battery for the whole circuit, retaining only the receiving instruments formerly shown. This arrangement is represented in Figs. 15, 16, and 17. Upon vibrating the steel reed of a receiver R, R′, at any station by any mechanical means, the corresponding reeds at all the other stations

are thrown into vibration, reproducing the signal. By attaching the steel reeds to the poles of a powerful permanent magnet, as shown in Fig. 19, the signals can be produced without the aid of a battery.

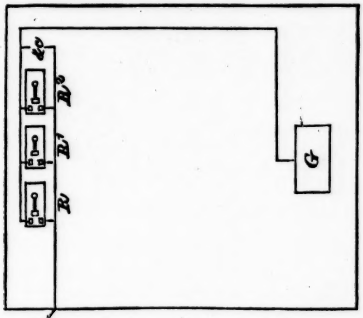

Fig. 17.

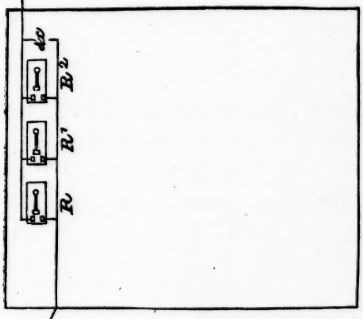

Fig. 16.

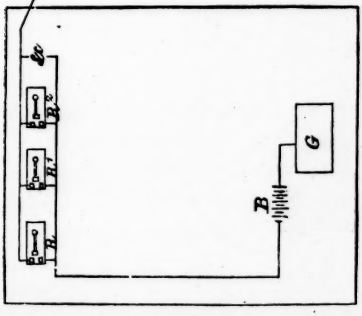

Fig. 15.

I have formerly stated that Helmholtz was enabled to produce vowel sounds artificially by combining musical tones of different

pitches and intensities. His apparatus is shown in Fig. 18. Tuning-

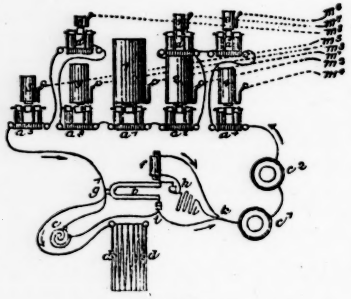

Fig. 18.*

forks of different pitch are placed between the poles of electro-magnets (a^1, a^2, &c.), and are kept in continuous vibration by the action of an intermittent current from the fork *b*. Resonators 1, 2, 3, &c., are arranged so as to reinforce the sounds, in a greater or less degree, according as the exterior orifices are enlarged or contracted.

Thus it will be seen that upon Helmholtz's plan the tuning-forks themselves produce tones of uniform intensity, the loudness being varied by an external reinforcement; but it struck me that the same results would be obtained, and in a much more perfect manner, by causing the tuning-forks themselves to vibrate with different degrees of amplitude. I therefore devised the apparatus shown in Fig. 19, which was my first form of articulating telephone. In this figure a harp of steel rods is employed attached to the poles of a permanent magnet N. S. When any one of the rods is thrown into vibration an undulatory current is produced in the coils of the electro-magnet E, and the electro-magnet E′ attracts the rods of

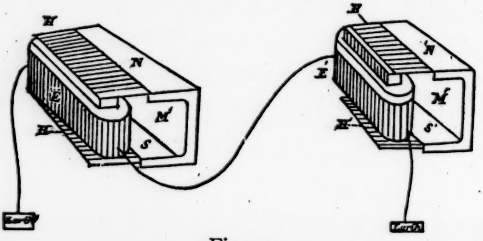

Fig. 19.

* The full description of this figure will be found in Mr. Alexander J. Ellis's translation of Helmholtz's work, "Theory of Tone."

the harp H′ with a varying force, throwing into vibration that rod which is in unison with that vibrated at the other end of the circuit. Not only so, but the amplitude of vibration in the one will determine the amplitude of vibration in the other, for the intensity of the induced current is determined by the amplitude of the inducing vibration, and the amplitude of the vibration at the receiving end depends upon the intensity of the attractive impulses. When we sing into a piano, certain of the strings of the instrument are set in vibration sympathetically by the action of the voice with different degrees of amplitude, and a sound, which is an approximation to the vowel uttered, is produced from the piano. Theory shows, that, had the piano a very much larger number of strings to the octave, the vowel sounds would be perfectly reproduced. My idea of the action of the apparatus, shown in Fig. 19, was this: Utter a sound in the neighborhood of the harp H, and certain of the rods would be thrown into vibration with different amplitudes. At the other end of the circuit the corresponding rods of the harp H′ would vibrate with their proper relations of force, and the *timbre* of the sound would be reproduced. The expense of constructing such an apparatus as that shown in Fig. 19 deterred me from making the attempt, and I sought to simplify the apparatus before venturing to have it made.

I have before alluded to the invention by my father of a system of physiological symbols for representing the action of the vocal organs, and I had been invited by the Boston Board of Education to conduct a series of experiments with the system in the Boston school for the deaf and dumb. It is well known that deaf mutes are dumb merely because they are deaf, and that there is no defect in their vocal organs to incapacitate them from utterance. Hence it was thought that my father's system of pictorial symbols, popularly known as visible speech, might prove a means whereby we could teach the deaf and dumb to use their vocal organs and to speak. The great success of these experiments urged upon me the advisability of devising methods of exhibiting the vibrations of sound optically, for use in teaching the deaf and dumb. For some time I carried on experiments with the manometric capsule of Koenig, and with the phonautograph of Léon Scott. The scientific apparatus in the Institute of Technology in Boston was freely placed at my disposal for these experiments, and it happened that at that time a student of the Institute of Technology, Mr. Maurey, had invented an improvement upon the phonautograph. He had succeeded in vibrating by the voice a stylus of wood about a foot in length which was attached to the membrane of the phonautograph, and

in this way he had been enabled to obtain enlarged tracings upon a plane surface of smoked glass. With this apparatus I succeeded in producing very beautiful tracings of the vibrations of the air for vowel sounds. Some of these tracings are shown in Fig. 20. I was much struck with this improved form of apparatus, and

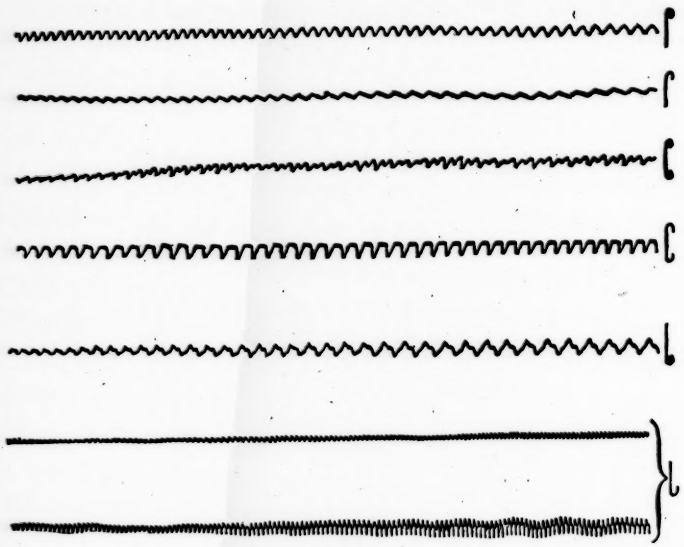

Fig. 20.

it occurred to me that there was a remarkable likeness between the manner in which this piece of wood was vibrated by the membrane of the phonautograph and the manner in which the *ossiculæ* of the human ear were moved by the tympanic membrane. I determined therefore to construct a phonautograph modeled still more closely upon the mechanism of the human ear, and for this purpose I sought the assistance of a distinguished aurist in Boston, Dr. Clarence J. Blake. He suggested the use of the human ear itself as a phonautograph, instead of making an artificial imitation of it. The idea was novel and struck me accordingly, and I requested my friend to prepare a specimen for me, which he did. The apparatus, as finally constructed, is shown in Fig. 21. The *stapes* was removed and a stylus of hay about an inch in length was attached to the end of the incus. Upon moistening the membrana-tympani and the ossiculæ with a mixure of glycerine and water, the necessary mobility of the parts was obtained; and upon singing into the external artificial ear the stylus

of hay was thrown into vibration, and tracings were obtained upon a plane surface of smoked glass passed rapidly underneath. While engaged in these experiments I was struck with the remarkable disproportion in weight between the membrane and the bones that were vibrated by it. It occurred to me that if a membrane as thin as tissue paper could control the vibration of bones that were, compared to it, of immense size and weight, why should not a larger and thicker membrane be able to vibrate a piece of iron in front of an electro-

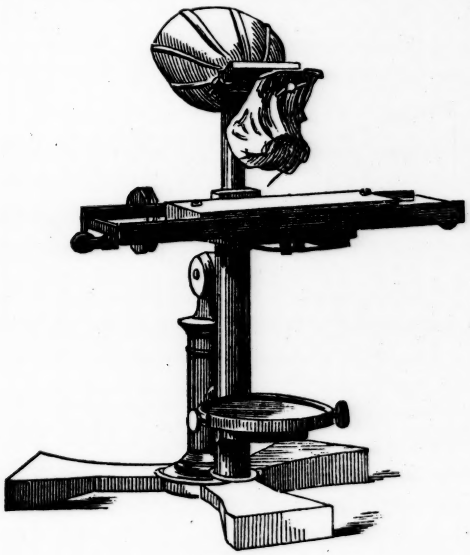

Fig. 21.

magnet, in which case the complication of steel rods shown in my first form of telephone, Fig. 19, could be done away with, and a simple piece of iron attached to a membrane be placed at either end of the telegraphic circuit.

Fig. 22 shows the form of apparatus that I was then employing for producing undulatory currents of electricity for the purposes of multiple telegraphy. A steel reed A was clamped firmly by one extremity to the uncovered leg *h* of an electro-magnet E, and the free end of the reed projected above the covered leg. When the reed A was vibrated in any mechanical way, the battery current was thrown into waves, and electrical undulations traversed the circuit B E W E′, throwing into vibration the corresponding reed

A′ at the other end of the circuit. I immediately proceeded to

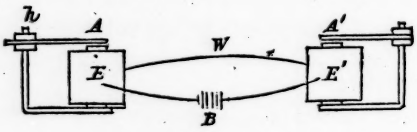

Fig. 22.

put my new idea to the test of practical experiment, and for this purpose I attached the reed A (Fig. 23) loosely by one extremity to the uncovered pole *h* of the magnet, and fastened the other

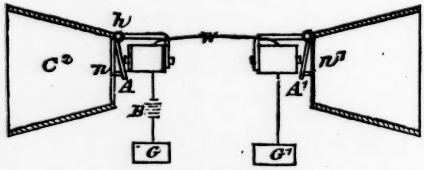

Fig. 23.

extremity to the centre of a stretched membrane of goldbeaters' skin *n*. I presumed that upon speaking in the neighborhood of the membrane *n* it would be thrown into vibration and cause the steel reed A to move in a similar manner, occasioning undulations in the electrical current that would correspond to the changes in the density of the air during the production of the sound; and I further thought that the change of the intensity of the current at the receiving end would cause the magnet there to attract the reed A′ in such a manner that it should copy the motion of the reed A, in which case its movements would occasion a sound from the membrane *n′* similar in *timbre* to that which had occasioned the original vibration.

The results, however, were unsatisfactory and discouraging. My friend Mr. Thomas A. Watson, who assisted me in this first experiment, declared that he heard a faint sound proceed from the telephone at his end of the circuit, but I was unable to verify his assertion. After many experiments attended by the same only partially-successful results, I determined to reduce the size and weight of the spring as much as possible. For this purpose I glued a piece of clock spring, about the size and shape of my thumb-nail, firmly to the centre of the diaphragm, and had a similar instrument at the other end (Fig. 24); we were then enabled to obtain distinctly audible effects. I remember an experiment made with this telephone, which at the time gave me

great satisfaction and delight. One of the telephones was placed in my lecture-room in the Boston University, and the other in the basement of the adjoining building. One of my students repaired to the distant telephone to observe the effects of articulate speech, while I

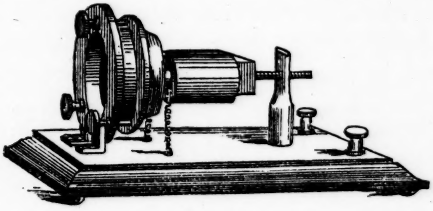

Fig. 24.

uttered the sentence, "Do you understand what I say?" into the telephone placed in the lecture-hall. To my delight an answer was returned through the instrument itself, articulate sounds proceeded from the steel spring attached to the membrane, and I heard the sentence, "Yes, I understand you perfectly." It is a mistake, however, to suppose that the articulation was by any means perfect, and expectancy no doubt had a great deal to do with my recognition of the sentence; still, the articulation was there, and I recognized the fact that the

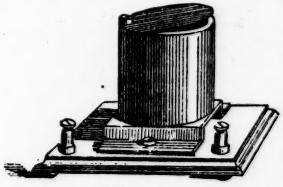

Fig. 25.

indistinctness was entirely due to the imperfection of the instrument. I will not trouble you by detailing the various stages through which the apparatus passed, but shall merely say that after a time I produced the form of instrument shown in Fig. 25, which served very well as a receiving telephone. In this condition my invention was exhibited at the Centennial Exhibition in Philadelphia. The telephone shown in Fig. 24 was used as a transmitting instrument, and that in Fig. 25 as a receiver, so that vocal communication was only established in one direction.

Another form of transmitting telephone exhibited in Philadelphia intended for use with the receiving telephone (Fig. 25) is represented by Fig. 26.*

*See Prescott's "Speaking Telephone," p. 73.

A platinum wire attached to a stretched membrane completed a voltaic circuit by dipping into water. Upon speaking to the membrane, articulate sounds proceeded from the telephone in the distant room. The sounds produced by the telephone became louder when dilute sulphuric acid, or a saturated solution of salt, was substituted for the water. Audible effects were also produced by the vibration of plumbago in mercury, in a solution of bichromate of potash, in salt and water, in dilute sulphuric acid, and in pure water.

The articulation produced from the instrument shown in Fig. 25 was remarkably distinct, but its great defect consisted in the fact that it could not be used as a transmitting instrument, and thus two telephones were required at each station, one for transmitting and one for receiving spoken messages.

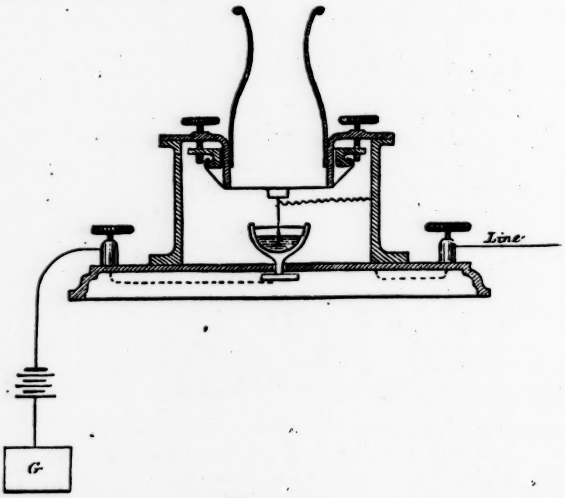

Fig. 26.

It was determined to vary the construction of the telephone shown in Fig. 24, and I sought by changing the size and tension of the membrane, the diameter and thickness of the steel spring, the size and power of the magnet, and the coils of insulated wire around their poles, to discover empirically the exact effect of each element of the combination, and thus to deduce a more perfect form of apparatus. It was found that a marked increase in the loudness of the sounds resulted from shortening the length of the coils of wire, and by enlarging the iron diaphragm which was glued to the membrane. In the latter case, also, the distinctness of the articulation was improved. Finally,

the membrane of goldbeaters' skin was discarded entirely, and a simple iron plate was used instead, and at once intelligible articulation was obtained. The new form of instrument is that shown in Fig. 27, and, as had been long anticipated, it was proved that the only use of the battery was to magnetize the iron core of the magnet, for the effects were equally audible when the battery was omitted, and a rod of magnetized steel substituted for the iron core of the magnet.

It was my original intention, as shown in Fig. 19, and it was always claimed by me, that the final form of telephone would be operated by

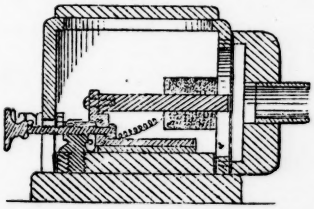

Fig. 27.

permanent magnets in place of batteries, and numerous experiments had been carried on by Mr. Watson and myself privately for the purpose of producing this effect.

At the time the instruments were first exhibited in public the results obtained with permanent magnets were not nearly so striking as when a voltaic battery was employed, wherefore we thought it best to exhibit only the latter form of instrument.

The interest excited by the first published accounts of the operation of the telephone led many persons to investigate the subject, and I doubt not that numbers of experimenters have independently discovered that permanent magnets might be employed instead of voltaic batteries. Indeed one gentleman, Professor Dolbear, of Tufts College, not only claims to have discovered the magneto-electric telephone, but I understand charges me with having obtained the idea from him through the medium of a mutual friend.

A still more powerful form of apparatus was constructed by using

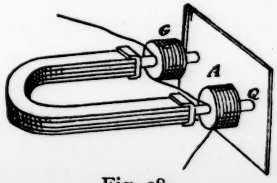

Fig. 28.

a powerful compound horse-shoe magnet in place of the straight rod which had been previously used (see Fig. 28). Indeed the sounds produced by means of this instrument were of sufficient loudness to be faintly audible to a large audience, and in this condition the instrument was exhibited in the Essex Institute, in Salem, Massachusetts, on the 12th February, 1877, on which occasion a short speech shouted into a similar telephone in Boston, sixteen miles away, was heard by the audience in Salem. The tones of the speaker's voice were distinctly audible to an audience of six hundred people, but the articulation was only distinct at a distance of about six feet. On the same occasion, also, a report of the lecture was

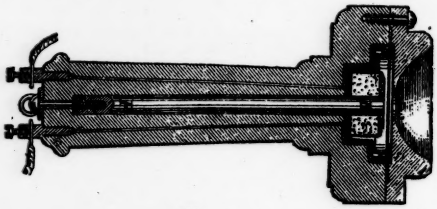

Fig. 29.

transmitted by word of mouth from Salem to Boston, and published in the papers the next morning.

From the form of telephone shown in Fig. 27 to the present form of the instrument (Fig. 29) is but a step. It is in fact the arrangement of Fig. 27 in a portable form, the magnet F H being placed inside the handle and a more convenient form of mouth-piece provided. The arrangement of these instruments upon a telegraphic circuit is shown in Fig. 30.

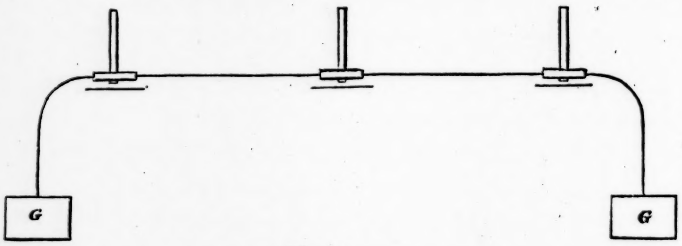

Fig. 30.

And here I wish to express my indebtedness to several scientific friends in America for their co-operation and assistance. I would specially mention Professor Peirce and Professor Blake, of Brown

University, Dr. Channing, Mr. Clarke, and Mr. Jones. In Providence, Rhode Island, these gentlemen have been carrying on together experiments seeking to perfect the form of apparatus required, and I am happy to record the fact that they communicated to me each new discovery as it was made, and every new step in their investigations. It was, of course, almost inevitable that these gentlemen should retrace much of the ground that had been gone over by me, and so it has happened that many of their discoveries had been anticipated by my own researches; still, the very honorable way in which they from time to time placed before me the results of their discoveries entitles them to my warmest thanks and to my highest esteem. It was always my belief that a certain ratio would be found between the several parts of a telephone, and that the size of the instrument was immaterial; but Professor Peirce was the first to demonstrate the extreme smallness of the magnets which might be employed. And here, in order to show the parallel lines in which we were working, I may mention the fact that two or three days after I had constructed a telephone of the portable form (Fig. 29) containing the magnet inside the handle, Dr. Channing was kind enough to send me a pair of telephones of a similar pattern, which had been invented by the Providence experimenters. The convenient form of mouth-piece shown in Fig. 29, now adopted by me, was invented solely by my friend Professor Peirce. I must also express my obligations to my friend and associate, Mr. Thomas A. Watson, of Salem, Massachusetts, who has for two years past given me his personal assistance in carrying on my researches.

In pursuing my investigations I have ever had one end in view, the practical improvement of electric telegraphy; but I have come across many facts which, while having no direct bearing upon the subject of telegraphy, may yet possess an interest for you.*

For instance, I have found that a musical tone proceeds from a piece of plumbago or retort-carbon when an intermittent current of electricity is passed through it, and I have observed the most curious audible effects produced by the passage of reversed intermittent currents through the human body. A rheotome was placed in circuit with the primary wires of an induction coil, and the fine wires were connected with two strips of brass. One of these strips was held closely against the ear, and a loud sound proceeded from it whenever the other slip was touched with the other hand. The strips of brass

* See *Researches in Telephony*.—Trans. of American Acad. of Arts and Sciences, vol. xii. p. 1.

were next held one in each hand. The induced currents occasioned a muscular tremor in the fingers. Upon placing my forefinger to my ear a loud crackling noise was audible, seemingly proceeding from the finger itself. A friend who was present placed my finger to his ear, but heard nothing. I requested him to hold the strips himself. He was then distinctly conscious of a noise (which I was unable to perceive) proceeding from his finger. In this case a portion of the induced currents passed through the head of the observer when he placed his ear against his own finger: and it is possible that the sound was occasioned by a vibration of the surfaces of the ear and finger in contact.

When two persons receive a shock from a Ruhmkorff's coil by clasping hands, each taking hold of one wire of the coil with the free hand, a sound proceeds from the clasped hands. The effect is not produced when the hands are moist. When either of the two touches the body of the other a loud sound comes from the parts in contact. When the arm of one is placed against the arm of the other, the noise produced can be heard at a distance of several feet. In all these cases a slight shock is experienced so long as the contact is preserved. The introduction of a piece of paper between the parts in contact does not materially interfere with the production of the sounds, but the unpleasant effects of the shock are avoided.

When an intermittent current from a Ruhmkorff's coil is passed through the arms a musical note can be perceived when the ear is closely applied to the arm of the person experimented upon. The sound seems to proceed from the muscles of the fore-arm and from the biceps muscle. Mr. Elisha Gray* has also produced audible effects by the passage of electricity through the human body.

An extremely loud musical note is occasioned by the spark of a Ruhmkorff's coil when the primary circuit is made and broken with sufficient rapidity; when two rheotomes of different pitch are caused simultaneously to open and close the primary circuit a double tone proceeds from the spark.

A curious discovery, which may be of interest to you, has been made by Professor Blake. He constructed a telephone in which a rod of soft iron, about six feet in length, was used instead of a permanent magnet. A friend sang a continuous musical tone into the mouthpiece of a telephone, like that shown in Fig. 29, which was connected with the soft iron instrument alluded to above. It was found that the

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* *Elisha Gray.* Eng. Pat. Spec. No. 2646, Aug. 1874.

loudness of the sound produced in this telephone varied with the direction in which the iron rod was held, and that the maximum effect was produced when the rod was in the position of the dipping-needle. This curious discovery of Professor Blake has been verified by myself.

When a telephone is placed in circuit with a telegraph line, the telephone is found seemingly to emit sounds on its own account. The most extraordinary noises are often produced, the causes of which are at present very obscure. One class of sounds is produced by the inductive influence of neighboring wires and by leakage from them, the signals of the Morse alphabet passing over neighboring wires being audible in the telephone, and another class can be traced to earth currents upon the wire, a curious modification of this sound revealing the presence of defective joints in the wire.

Professor Blake informs me that he has been able to use the railroad track for conversational purposes in place of a telegraph wire, and he further states that when only one telephone was connected with the track the sounds of Morse operating were distinctly audible in the telephone, although the nearest telegraph wires were at least forty feet distant.

Professor Peirce has observed the most curious sounds produced from a telephone in connection with a telegraph wire during the aurora borealis; and I have just heard of a curious phenomenon lately observed by Dr. Channing. In the city of Providence, Rhode Island, there is an overhouse wire about one mile in extent with a telephone at either end. On one occasion the sound of music and singing was faintly audible in one of the telephones. It seemed as if some one were practising vocal music with a piano-forte accompaniment. The natural supposition was that experiments were being made with the telephone at the other end of the circuit, but upon inquiry this proved not to have been the case. Attention having thus been directed to the phenomenon, a watch was kept upon the instruments, and upon a subsequent occasion the same fact was observed at both ends of the line by Dr. Channing and his friends. It was proved that the sounds continued for about two hours, and usually commenced about the same time. A searching examination of the line disclosed nothing abnormal in its condition, and I am unable to give you any explanation of this curious phenomenon. Dr. Channing has, however, addressed a letter upon the subject to the editor of one of the Providence papers, giving the names of such songs as were recognized, with full details of the observations, in the hope that publicity may lead to the discovery of the performer, and thus afford a solution of the mystery.

My friend Mr. Frederick A. Gower communicated to me a curious observation made by him regarding the slight earth connection required to establish a circuit for the telephone, and together we carried on a series of experiments with rather startling results. We took a couple of telephones and an insulated wire about 100 yards in length into a garden, and were enabled to carry on conversation with the greatest ease when we held in our hands what should have been the earth wire, so that the connection with the ground was formed at either end through our bodies, our feet being clothed with cotton socks and leather boots. The day was fine, and the grass upon which we stood was seemingly perfectly dry. Upon standing upon a gravel walk the vocal sounds, though much diminished, were still perfectly intelligible, and the same result occurred when standing upon a brick wall one foot in height, but no sound was audible when one of us stood upon a block of freestone.

One experiment which we made is so very interesting that I must speak of it in detail. Mr. Gower made earth connection at his end of the line by standing upon a grass plot, whilst at the other end of the line I stood upon a wooden board. I requested Mr. Gower to sing a continuous musical note, and to my surprise the sound was very distinctly audible from the telephone in my hand. Upon examining my feet I discovered that a single blade of grass was bent over the edge of the board, and that my foot touched it. The removal of this blade of grass was followed by the cessation of the sound from the telephone, and I found that the moment I touched with the toe of my boot a blade of grass or the petal of a daisy the sound was again audible.

The question will naturally arise, Through what length of wire can the telephone be used? In reply to this I may say that the maximum amount of resistance through which the undulatory current will pass, and yet retain sufficient force to produce an audible sound at the distant end, has yet to be determined; no difficulty has, however, been experienced in laboratory experiments in conversing through a resistance of 60,000 ohms, which has been the maximum at my disposal. On one occasion, not having a rheostat at hand, I may mention having passed the current through the bodies of sixteen persons, who stood hand in hand. The longest length of real telegraph line through which I have attempted to converse has been about 250 miles. On this occasion no difficulty was experienced so long as parallel lines were not in operation. Sunday was chosen as the day on which it was probable other circuits would be at rest.

Conversation was carried on between myself, in New York, and Mr. Thomas A. Watson, in Boston, until the opening of business upon the other wires. When this happened the vocal sounds were very much diminished, but still audible. It seemed, indeed, like talking through a storm. Conversation though possible could be carried on with difficulty, owing to the distracting nature of the interfering currents.

I am informed by my friend Mr. Preece that conversation has been successfully carried on through a submarine cable, sixty miles in length, extending from Dartmouth to the Island of Guernsey, by means of hand telephones similar to that shown in Fig. 30.

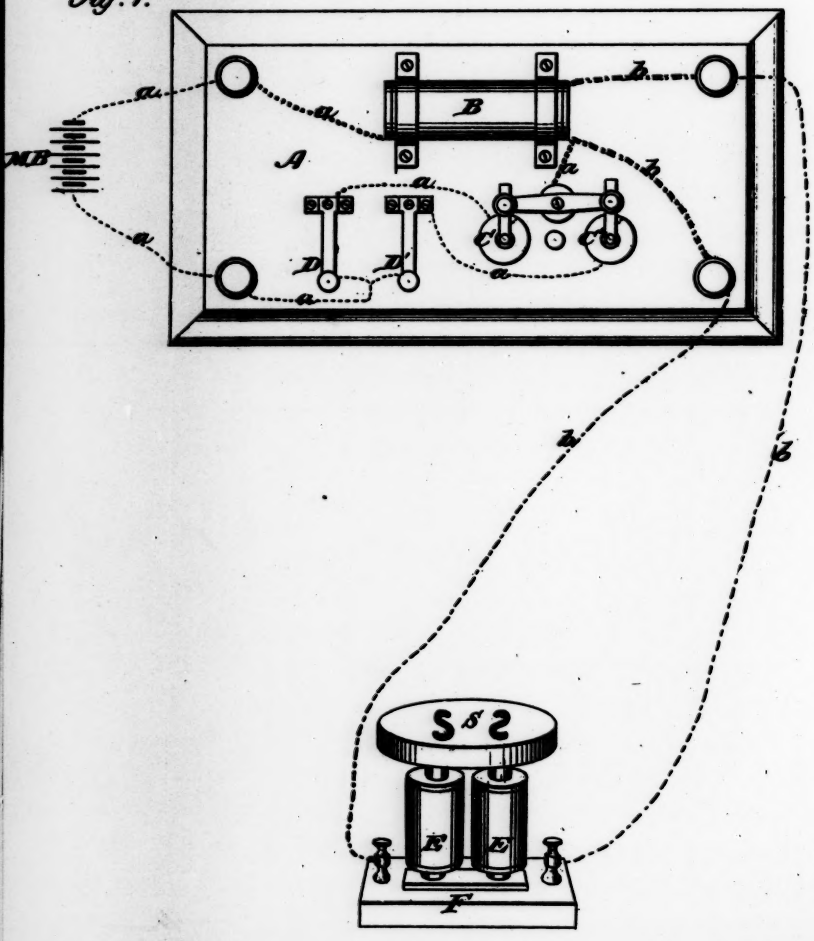
2 Sheets--Sheet 1.

E. GRAY.

Electric Telegraph for Transmitting Musical Tones.

No. 166,095. Patented July 27, 1875.

Fig. 1.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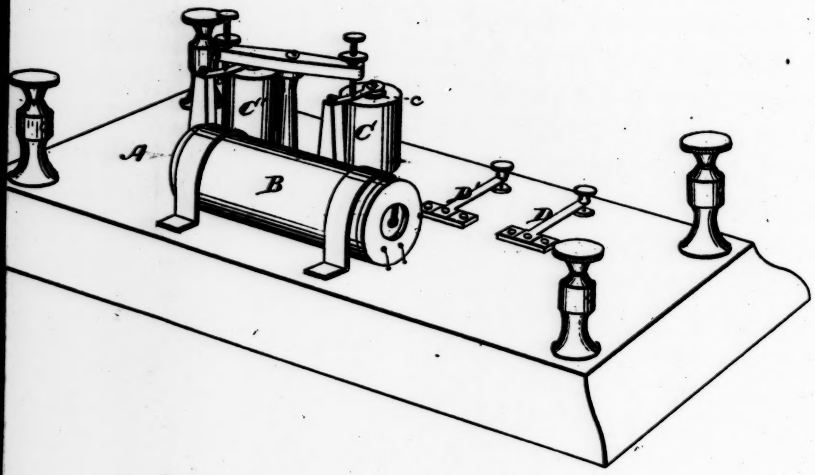
2 Sheets--Sheet 2.

E. GRAY.

ctric Telegraph for Transmitting Musical Tones.

. 166,095. Patented July 27, 1875.

Fig. 2.



ELISHA GRAY, OF CHICAGO, ILLINOIS.

IMPROVEMENT IN ELECTRIC TELEGRAPHS FOR TRANSMITTING MUSICAL TONES.

Specification forming part of Letters Patent No. **166,095**, dated July 27, 1875; application filed January 19, 1875.

To all whom it may concern:

Be it known that I, ELISHA GRAY, of Chicago, in the county of Cook and State of Illinois, have invented a certain new and useful Apparatus for Transmitting Musical Impressions or Sounds Telegraphically, of which I hereby declare the following to be a full, clear, and exact description:

My invention relates to what I term an "electro-harmonic telegraph," and is based upon the fact well known to electricians that an electro-magnet elongates under the action of the electric current, and contracts again when the current ceases. Consequently a succession of impulses or interruptions will cause the magnet to vibrate, and if these vibrations be of sufficient frequency a musical tone will be produced, the pitch of which will depend upon the rapidity of the vibrations.

I have discovered that by interrupting an electric current at the transmitting end of a line with sufficient frequency to produce a musical tone by an instrument vibrated by said interruptions, and transmitting the impulses thus induced to an electro-magnet at the receiving end of the line, the latter will vibrate synchronously with the transmitting-instrument, and thus produce a musical tone or note of a corresponding pitch. The object of my invention is to utilize this discovery for the transmission of intelligible signals to a distance by electricity; to which end my improvement consists in the combination of a telegraphic circuit, a series of circuit-breakers capable of producing musical tones of different pitch, a series of keys for simultaneously or successively throwing said circuit-breakers into or out of operation, and an electro-magnet receiver, which is thrown into operation by the transmitter, whereby tones of different pitch may be reproduced at the receiving end of the line by the use of a single circuit.

In the accompanying drawings, Figure 1 shows a plan view of the transmitting part of my improved apparatus, the receiver appearing in perspective. Fig. 2 is a view, in perspective, of the transmitter.

The transmitting apparatus is mounted upon a base-board, A, as usual. The induction-coil B has the usual primary and secondary circuits. An ordinary automatic electrotome, C, has a circuit-closing spring, *c*, so adjusted as when in action, to produce a musical tone ac cording to its length, thickness, and adjus ment. A common telegraph-key, D, is place in the primary circuit to make or break th battery-connection. In the drawings I hav shown two electrotomes of identical constru tion, but of different pitch, and two keys, bot the keys and electrotomes being placed in th primary circuit, which is so divided that par of the circuit passes through each key and it corresponding electrotome. The number o electrotomes may be increased, so that tone extending through two or more octaves ma be produced. An ordinary electro-magnet i provided at the receiving end of the line.

The operation of the apparatus is as follows In the arrangement shown in the drawing when a key is closed the primary circuit wi pass from the battery H through that key an its corresponding electrotome, and will be aut matically interrupted in the usual manne The spring of the electrotome will thus b caused to vibrate rapidly and to produce tone, the pitch of which is determined by th rate of vibration. It is obvious that severa keys may be depressed simultaneously. Thes vibrations or interruptions of the current wi simultaneously produce in the secondary ci cuit of the induction-coil a series of induce currents or impulses corresponding in numbe with the vibrations of the electrotome, and a the receiving electro-magnet is connected wit this circuit it will be caused to vibrate, thu producing a tone of corresponding pitch, th sound of which may be intensified by the us of a hollow cylinder, S, of metal, placed on th poles of the magnet.

When a single electrotome is thrown in action, its corresponding tone will be repr duced on the sounder by the magnet. Whe electrotomes of different pitch are successive operated, their tones w ill be corresponding reproduced by the rece iver, and when two more electrotomes are s multaneously sounde the tone of each will sti ll be reproduced wit out confusion on the so nder, by which mea I am enabled to reprod uce melodies or tune

Mechanical circuit-b eakers might be su stituted for the autom atic vibrating electr tome, hereinbefore des cribed, and I have,

ict, used such mech anical circuit-breakers of arious construction; but I found the electro- me more satisfactory in practice.

In this instance the receiver is shown and escribed as operated by the induced current f the secondary coil; but the secondary or xtra current of a primary coil may be used stead thereof with good effect.

My apparatus is specially adapted to tele- raphing on long land and submarine lines. y it letters and signals can be represented y tones differing in pitch; or the ordinary lorse signals can be made by short and long terruptions in a prolonged tone of the same itch, thus securing great rapidity of trans- ission.

An application for Letters Patent of the nited States, filed by me April 18, 1874, hows an apparatus somewhat similar to the ne herein described, for transmitting musical ones through animal tissue to a resonant elec- rical receiver. I do not, therefore, claim here- anything therein shown. Neither do I claim erein the combination, with a main line, of n intermittent circuit-breaker, or a series hereof, each adapted to throw upon the line definite number of electrical impulses per unit of time, and a key or keys, one for and controlling each such circuit-breaker, as it constitutes the subject-matter of another application filed by me February 23, 1875. The combination of a telegraphic circuit, an automatic circuit-breaker capable of producing a musical tone, and an electro-magnet receiver which reproduces the tone by being thrown into vibration by impulses generated by the circuit-breaker, is not, broadly, claimed herein, as this combination constitutes a part of the subject-matter of said application, also.

I claim as my own invention—

The combination of a telegraphic circuit, a series of circuit-breakers capable of producing musical tones of different pitch, a series of keys for simultaneously or successively throwing said circuit-breakers into or out of operation, and an electro-magnet receiver, which is thrown into operation by the transmitters, whereby tones of different pitch may be reproduced at the receiving end of the line by the employment of a single circuit.

ELISHA GRAY.

Witnesses:
E. C. DAVIDSON,
WM. J. PEYTON.

537

Circuit Court of the United States,

EASTERN DISTRICT OF PENNSYLVANIA.

AMERICAN BELL TELEPHONE CO., ET AL.

vs.

CLAY COMMERCIAL TELEPHONE. CO., ET AL.

At the final hearing on the merits, and after the oral argument of the defendants' counsel (no brief, or printed or written argument having been offered by the defendants), the complainants offer in evidence the following: —

(1.) Certified copy from the records of the Patent Office of deed Bell Telephone Co. to American Bell Telephone Co., dated April 23, 1881, and recorded in Patent Office, July 6, 1881, Lib. B 27, page 102 of Transfers of Patents.

(2.) Also the original of same.

And produce in court Charles Eustis Hubbard, already examined as a witness for the complainants, and offer to prove by him the due execution of said instrument. The examination of the witness is waived.

(4.) Also produce original deed Thomas Sanders to American Bell Telephone Company, dated June 21, 1880, and offer a witness to prove the execution thereof, the examination of which witness is waived.

(5.) Also the affidavit of George L. Roberts, Esq.

The said deeds are as follows: —

DEPARTMENT OF THE INTERIOR.

UNITED STATES PATENT OFFICE.

To all persons to whom these presents shall come, GREETING: —

This is to certify that the annexed is a true copy from the Records

of this Office, of an instrument of writing executed by the Bell Telephone Company, April 23, 1881.

Recorded in Liber B 27, page 101.

Said record has been carefully compared with the original, and is a correct transcript thereof.

In testimony whereof, I, Benj. Butterworth, Commissioner of Patents, have caused the seal of the Patent Office to be affixed this eighteenth day of March, in the year of our Lord one thousand eight hundred and eighty-four, and of the Independence of the United States the one hundred and eighth.

(Signed) BENJ. BUTTERWORTH,

{Seal of Patent Office.} *Commissioner.*

[DEED BELL TELEPHONE COMPANY TO AMERICAN BELL TELEPHONE COMPANY.]

Recorded July 6, 1881, Liber B 27, page 101, of Transfers of Patents.

Know all men by these presents, that the Bell Telephone Company, a corporation created under the laws of the Commonwealth of Massachusetts, in consideration of one dollar and other valuable considerations to it paid by the American Bell Telephone Company, a corporation created under said laws, the receipt whereof is hereby acknowledged, does hereby grant and convey unto said American Bell Telephone Company the exclusive right, under the following patents, to the State of Massachusetts, viz.: Letters Patent, No. 174,465, issued March 7, 1876, to Alexander Graham Bell for an improvement in telegraphy; and Letters Patent, No. 186,787, issued January 30, 1877, to said Bell for an improvement in electric telegraphy, and in and to the inventions therein described, or intended to be described; and does further grant, assign and convey to said American Bell Telephone Company any and all other right, title and interest now remaining to it, said Bell Telephone Company, in, to and under said Letters Patent and inventions.

To have and to hold the same to the said American Bell Telephone Company, its successors and assigns, to their own use and behoof forever.

OFFERED AT THE HEARING.

This instrument is made at the request of the National Bell Telephone Company in pursuance of an agreement between said Bell Telephone Company and said National Bell Telephone Company, dated March 20, 1879; said American Bell Telephone Company being the appointee of said National Bell Telephone Company to receive this conveyance; and in pursuance of an agreement between said National Bell Telephone Company and said American Bell Telephone Company, dated May 8, 1880.

In witness whereof said Bell Telephone Company has caused its corporate seal to be hereto affixed, and these presents to be signed in its name and behalf by W. H. Forbes, its president, thereto duly authorized, this twenty-third day of April, A. D. 1881.

THE BELL TELEPHONE COMPANY,

{ Seal of Bell Tel. Co. }

By W. H. Forbes,

Prest.

[Deed Sanders to American Bell Telephone Co.]

Know all men by these presents, that I, Thomas Sanders, of Haverhill, in the State of Massachusetts, in consideration of one dollar to me paid by the American Bell Telephone Company, a corporation established under the laws of the State of Massachusetts, the receipt whereof is hereby acknowledged, do hereby sell, grant, assign and convey unto said American Bell Telephone Company, all my right, title and interest in and to the following-named patents of the United States, and the inventions therein described or intended to be described, viz.: —

Letters Patent No. 174,465, issued March 7, 1876, to Alexander Graham Bell for an improvement in telegraphy; and Letters Patent No. 178,399, issued June 6, 1876, to said Bell for an improvement in Telephonic Telegraph Receivers.

To have and to hold the same to the said American Bell Telephone Company, its successors and assigns, to their own use and behoof forever.

Witness my hand and seal this twenty-first day of June, A. D. 1880.

THOMAS SANDERS. [seal]

In presence of

W. P. Montague.

ADDITIONAL PROOF FOR COMPLAINANTS.

CIRCUIT COURT OF THE UNITED STATES,

EASTERN DISTRICT OF PENNSYLVANIA, ss.

IN EQUITY.

AMERICAN BELL TELEPHONE COMPANY ET AL.

v.

THE CLAY COMMERCIAL TELEPHONE COMPANY ET AL.

AFFIDAVIT OF GEORGE L. ROBERTS.

I, George L. Roberts, of lawful age, being duly sworn, depose and say: —

I am a counsellor at law, and reside in Boston, Mass.

As counsel for the plaintiffs in this case, I alone put in the proof of title, as appears on Page 52 of the complainants' printed record.

I believed that the deeds introduced in evidence made a sufficient title on which to maintain this suit, and now so believe. I probably, at some time, had known of the existence of a deed, *Bell Telephone Company* to *American Bell Telephone Company*, dated April 23, 1881; but, until I saw the deed to-day, I did not know that it contained in terms a grant or release of the Bell Patents, No. 174,465, and No. 186,787, referred to in the bill. I have no recollection of reading or seeing that deed, or a copy of it, until to-day.

I did not, until to-day, know of the existence of the deed, Sanders to American Bell Telephone Company, dated June 21, 1880.

GEO. L. ROBERTS.

UNITED STATES OF AMERICA,
DISTRICT AND COMMONWEALTH OF MASSACHUSETTS,
SUFFOLK, ss. JUNE 9, 1885.

Personally appeared George L. Roberts, above named, and made oath that the foregoing affidavit by him subscribed is true.

[SEAL OF COMMISSIONER] JOHN G. STETSON,
U. S. Commissioner.

[ENDORSED.]

No. 15 April Sess., 1884.
C. C. U. S., E. D. of Pa.

AMERICAN BELL TELEPHONE COMPANY ET AL.
v.
THE CLAY COMMERCIAL TELEPHONE COMPANY ET AL.

ADDITIONAL PROOF OF COMPLAINANTS.

Ordered to be filed and made part of the record, June 18, '85.
W. McK.,
C. J.

Filed June 19, 1885.

IN THE

Circuit Court of the United States,

EASTERN DISTRICT OF PENNSYLVANIA.

IN EQUITY.

THE AMERICAN BELL TELEPHONE COMPANY ET AL.

v.

THE CLAY COMMERCIAL TELEPHONE COMPANY ET AL.

IN THE MATTER OF ADDITIONAL PROOFS FOR THE COMPLAINANTS, OFFERED AT THE HEARING.

And now, to wit, June 5th, A. D. 1885, this cause having been heard at the final hearing on the bill, answer, and proofs, and the several arguments of the counsel for the plaintiffs and the counsel for the defendants having closed, the counsel for the plaintiffs ask leave of the court to offer in evidence, and file, as evidence in the said court on the part of the plaintiffs, certain papers that had not been produced and offered in evidence before the examiner or otherwise.

To this offer the counsel for the defendants then and there objected and excepted, which said objections and exceptions were overruled, and the court admitted said evidence and granted leave to the defendants to file of record their said objections and exceptions thereto.

And afterward, to wit, on the 10th day of June, A. D. 1885, the plaintiffs offer as evidence, and file, the following papers, to wit:

1. A paper purporting to be a certified copy from the records of the Patent Office of deed Bell Telephone Company to American Bell Telephone Company, dated April 23d, 1881, and recorded in the Patent Office July 6th, 1881, Liber B 27, page 101 of Transfers of Patents.

2. A paper purporting to be the original of the same.

3. A paper purporting to be original deed of Thomas Sanders to the American Bell Telephone Company, dated June 21st, 1880.

4. A paper purporting to be an affidavit of George L. Roberts, Esq.

And the counsel for the defendants object to the offer, and to now re-

ceiving in evidence the said paper purporting to be a certified copy from the records of the Patent Office of a deed from the Bell Telephone Company to the American Bell Telephone Company, dated April 23d, A. D. 1881, and recorded in the Patent Office July 6th, 1881, in Liber B 27, page 101 of Transfers of Patents, and to the paper purporting to be the original of the same, and in support of the objection suggest and allege the following reasons, among others:

1. Because the said alleged grant or conveyance is mentioned and described in paragraph three of the plaintiffs' bill of complaint as part of the alleged title acquired by the American Bell Telephone Company, and should have been offered in evidence regularly at the taking of evidence before the examiner in this cause, and cannot now be offered in evidence at bar and after the close of the final argument.

2. Because the offer of the said papers should have been referred to the examiner for proper proof, and to enable the defendants to take the proper exceptions thereto, that the same might regularly appear upon the record.

3. Because no proper or lawful evidence has been produced to show that the said Bell Telephone Company, by whom the said deed purports to have been made, is or ever was "a corporation created under the laws of the Commonwealth of Massachusetts," as in said alleged grant or conveyance mentioned and set forth, and there is no proper or lawful evidence that the said American Bell Telephone Company, to whom said deed purports to have been made, is or ever was "a corporation created under said laws," as therein alleged and set forth. On the contrary, the defendants deny that the said Bell Telephone Company ever became or was a legal or duly constituted corporation; and the defendants pray that the plaintiffs may be required by the court to make due proof of the incorporation of the said Bell Telephone Company, and of its right to make said alleged grant or conveyance.

4. Because there is no due proof of the ownership by the said Bell Telephone Company of the title to the letters patent aforesaid, or of its legal right to own or hold such property; and there is no due proof of the right, title, and authority of the said Bell Telephone Company to grant and convey to the said American Bell Telephone Company the exclusive right in and by the said papers purporting to be granted and conveyed.

5. Because in the said alleged grant or conveyance it is mentioned and set forth that "this instrument is made at the request of the National

Bell Telephone Company, in pursuance of an agreement between said Bell Telephone Company and said National Bell Telephone Company, dated March 20th, 1879; said American Bell Telephone Company being the appointee of said National Bell Telephone Company to receive this conveyance; and in pursuance of an agreement between said National Bell Telephone Company and said American Bell Telephone Company, dated May 8th, 1880." And when the plaintiffs were before the examiner and were producing their proofs, Charles Eustis Hubbard, one of the witnesses for the plaintiffs, testified concerning an agreement between the Bell Telephone Company and the National Bell Telephone Company, dated March 20th, 1879, and an agreement between the National Bell Telephone Company and the American Bell Telephone Company, dated May 8th, 1880, whereupon the counsel for the defendants then and there called upon the counsel for the plaintiffs to produce the said two agreements, and the counsel for the plaintiffs then and there declined to produce the said two agreements, as appears by the testimony on page 103 of the plaintiffs' printed record. And the defendants pray that the plaintiffs may now be required by the court to produce the said two agreements mentioned in the said alleged grant or conveyance, which the defendants aver, upon information and belief, are the same two agreements mentioned by the said Charles Eustis Hubbard in his said testimony, which the plaintiffs then refused and have since continued to refuse to produce.

6. Because the plaintiffs neglected or refused to produce and offer in evidence before the examiner the said alleged grant or conveyance, and no adequate or sufficient evidence is now offered to the court to account for or excuse such neglect or refusal.

7. Because the said papers and the said alleged grant and conveyance are otherwise irrelevant and inadmissible.

And the counsel for the defendants further object to the offer, and to the now receiving in evidence, of the said paper purporting to be the deed of Thomas Sanders to the American Bell Telephone Company, dated the 21st day of June, A. D. 1880, and suggest and allege in support of said objection the following reasons, among others:

1. Because it is alleged in paragraph four of the plaintiffs' bill of complaint that "the sole right to manufacture electric speaking telephones under said patents thereby became and still is vested in the said American Bell Telephone Company, and the only right granted to or possessed by any persons other than the said American Bell Telephone Company

under said patents has been and is the right to use telephones procured from said American Bell Telephone Company and its predecessors, upon payment of stated royalties under said two patents to the said American Bell Telephone Company;" and the alleged title of the said American Bell Telephone Company is further mentioned and described in paragraph three of the plaintiffs' bill of complaint; and the said alleged deed of the said Thomas Sanders to the American Bell Telephone Company, dated June 21st, 1880, should have been offered in evidence regularly at the taking of evidence before the examiner in this cause as part of the alleged title acquired by the American Bell Telephone Company, and cannot now be offered in evidence at bar and after the close of the argument.

2. Because the offer of the said deed in evidence should have been referred to the examiner in order that the defendants might have an opportunity to inquire into the circumstances connected with the making of the said deed, and into the nature and extent of the title and interest of the said Thomas Sanders, and into the relevancy of said deed to the alleged title of the plaintiffs, and into all other matters and things connected therewith, and to offer evidence, if need be, touching the same.

3. Because there is no proper or legal evidence that the said alleged deed was ever signed by the said Thomas Sanders.

4. Because there is no proper or legal evidence that the said alleged deed was ever delivered by the said Thomas Sanders to the American Bell Telephone Company, nor is there any proof of the ownership, possession, or custody of said paper from the time of its alleged execution, June 21st, 1880, down to the time of the making of the said affidavit of George L. Roberts, Esq., counsel of the plaintiffs, June 9th, 1885, in which affidavit it is stated that he, the said counsel, did not until the day when he made said affidavit, "know of the existence of the deed, Sanders to the American Bell Telephone Company, dated June 21st, 1880," although on November 21st, 1884, Charles Eustis Hubbard, who was clerk of the American Bell Telephone Company and of the Bell Telephone Company, as appears on plaintiffs' printed record, interrogatory eleven, page ninety-seven, was called by the plaintiffs as a witness, and testified, as appears on said printed record, cross-interrogatory twenty-three, page one hundred and one, that "Mr. Bell, Mr. Hubbard, and Mr. Sanders owned the inventions and patents in equal third parts;" whereby the plaintiffs and their counsel more than six months ago were not only put upon inquiry as to the outstanding title and interest of the said Thomas Sanders, but were distinctly notified and informed by their own witness of the existence thereof.

5. Because the said alleged deed does not show, nor does the bill of complaint state, what right, title, and interest the said Thomas Sanders owned in and to the said letters patent, nor does said deed or bill specifically describe the right, title, and interest sold, granted, assigned, and conveyed by the said Thomas Sanders to the American Bell Telephone Company in and by the said alleged deed.

6. Because there is no proper or lawful evidence that the said American Bell Telephone Company, the grantee in said deed, is or ever was "a corporation established under the laws of the State of Massachusetts," as in the said alleged deed mentioned, described, and set forth, or was or is, as a corporation, entitled to receive said transfer.

7. Because the plaintiffs failed and neglected to produce and offer in evidence before the examiner the said alleged deed, and no adequate or sufficient evidence is now offered to the court to account for or excuse such neglect or refusal; and the plaintiffs themselves, for aught that appears, had the same knowledge, and the counsel of the plaintiffs had the same means of knowledge heretofore on the subject as at the present time.

8. Because the said alleged deed is not mentioned or referred to in the bill of complaint, or set up as a part of the plaintiffs' title, or as being in anywise connected therewith, and is no part of the contents of the bill as sworn to, but is entirely new and independent matter, and is a source of title additional to and inconsistent with the title set up in the bill.

9. Because the said alleged deed is otherwise irrelevant and inadmissible, and as it is new matter, and a new source of title, cannot be given in evidence, until proper averments and additions in that behalf have been first made in and to the bill of complaint.

10. Because the defendants did not at the time of said offers waive the examination of Charles Eustis Hubbard, or of Thomas Sanders, or waive any other matter or thing, but on the contrary objected to the admissibility of said offers, and contended that said offers should be referred to the examiner to be duly proven before him.

The counsel for the defendants further object to the offer, and to the now receiving in evidence of the said paper purporting to be the affidavit of the said George L. Roberts, Esq., and allege the following reasons among others:

1. Because the said affidavit states no adequate or sufficient reason for not giving the said papers in evidence before the examiner.

2. Because the said affidavit is a voluntary expression of opinion upon the sufficiency of the evidence in the cause, and upon a matter of law to be decided by the court.

3. Because the said affidavit is otherwise irrelevant and inadmissible.

Finally, should it hereafter be decided by the appellate court that the receiving in evidence of the papers now offered by the plaintiffs is a matter of judicial discretion, not properly reviewable on appeal, the practical result of the action now asked to be taken by the court would be that the plaintiffs are allowed at this time to put in evidence a paper that is set up in the bill as a part of their chain of title, namely, the transfer by the Bell Telephone Company to the American Bell Telephone Company, dated April 23d, 1881, and also to put in evidence another paper that is not mentioned or set up in the bill, but which is offered now as a new and independent source of title, namely, the alleged transfer from Thomas Sanders to the American Bell Telephone Company, while at the same time the defendants are thus entirely deprived of their right to investigate by cross-examination and by testimony on their part, the facts and circumstances touching said papers respectively and their connection with the cause, and are also deprived of the opportunity of taking exceptions to the admission and relevancy of said papers in such proper manner and form that the exceptions may be reviewed, if need be, in the appellate court.

The counsel for the defendants object, therefore, to the respective offers of the counsel for the plaintiffs, and to now receiving in evidence each and every of the papers aforesaid, for the reasons aforesaid, among others.

The court having overruled the foregoing objections respectively, and admitted the said several papers in evidence, the defendants, by their counsel, object and except to the overruling of said exceptions, and to the admission of each and every of the said papers, and by leave of the court, the defendants now here file of record in the said cause the foregoing objections and exceptions.

[ENDORSED.]

No. 15. April, '84.

C. C. U. S., E. D. of Pa.

AMERICAN BELL TEL. CO. ET AL.

v.

CLAY COMMERCIAL TEL. CO. ET AL.

DEFENDANTS' EXCEPTIONS TO COMPLAINANTS' ADDITIONAL PROOFS.

Ordered to be filed and made part of record, June 18, '85.

W. McK.,
C. J.

Filed June 19, 1885.

by this court that the several Letters Patent upon which this suit is brought, viz.: Letters Patent granted to Alexander Graham Bell for an improvement in telegraphy, dated March 7, 1876, and numbered No. 174,465, and Letters Patent granted to said Bell for an improvement in electric telegraphy, numbered No. 186,787, and dated January 30, 1877, are good and valid in law; that the said Alexander Graham Bell was the original and first inventor of the inventions described in said several Letters Patent, Nos. 174,465 and 186,787; that the title thereto, and to the inventions described and claimed therein, is vested in the complainants, the American Bell Telephone Company; and that the said defendants, the Clay Commercial Telephone Company, John C. Scott, James McMillan, George W. Bratton, Samuel P. Godwin, Henry Clay, John J. Bailey, John Marston, Jr., Thomas C. Else, James McC. Creighton and Joseph Wright,

have infringed the fifth claim of said Letters Patent, No. 174,465, and the third, fifth, sixth, seventh and eighth claims of said Letters Patent, No. 186,787, and the exclusive rights of the complainants under the same.

And it is further ordered, adjudged and decreed (the complainants in open court, and to facilitate an appeal by defendants, waiving a reference to a master to take an account of the profits and damages), that said profits and damages be, and they are hereby assessed at the sum of one dollar.

And it is further ordered, adjudged and decreed, that the said defendant, the Clay Commercial Telephone Company, do pay to the said complainants the said sum of one dollar profits and damages; and also that the said defendants the Clay Commercial Telephone Company, John C. Scott, James McMillan, George W. Bratton, Samuel P. Godwin, Henry Clay, John J. Bailey, John Marston, Jr., Thomas C. Else, James McC. Creighton and Joseph Wright, do

pay complainants' costs in this suit, hereby taxed at eight hundred and thirty-two dollars and eighty-five cents, and that complainants have judgment and execution therefor; and also that the said defendants, the Clay Commercial Telephone Company, John C. Scott, James McMillan, George W. Bratton, Samuel P. Godwin, Henry Clay, John J. Bailey, John Marston, Jr., Thomas C. Else, James McC. Creighton and Joseph Wright, their and each of their clerks, attorneys, agents, servants and workmen, and all others acting under or with them, be perpetually enjoined and restrained from making, selling or using the said improvements, patented as aforesaid, or either of either of them, and that an injunction do issue accordingly.

And it is further ordered, adjudged and decreed, that as to the defendants, Alonzo P. Douglass and W. Harrison Godwin, the bill be dismissed without costs.

By the Court, Apl. 12, 1886.

[ENDORSED.]
15. April Sess., 1884.

C. C. U. S., E. D. of Pa.

THE AMERICAN BELL TELEPHONE CO. ET AL.
v.
THE CLAY COMMERCIAL TELEPHONE COMPANY ET AL.

DECREE.

Entered and Filed April 12, 1886.

And afterwards, to wit, on the 15th day of April, A. D. 1886, the respondents, by William W. Ker, Esquire, and Furman Sheppard, Esquire, their counsel, come into court here and pray for an appeal to the Supreme Court of the United States, which being read, is as follows, to wit:

AMERICAN BELL TELEPHONE COMPANY ET AL. *v.* CLAY COMMERCIAL TELEPHONE COMPANY ET AL.	U. S. CIRCUIT COURT, EASTERN DISTRICT OF PENNSYLVANIA, APRIL SESSIONS, 1884. No. 15.

And now, April 15th, 1886, William W. Ker and Furman Sheppard, Esqs., of counsel for the defendants, appear in open court and pray an appeal to the Supreme Court of the United States from the order, decree and judgment of this court against the defendants, entered April 12th, 1886. Whereupon the same is allowed, with security in the sum of sixteen hundred dollars.

BY THE COURT.

[ENDORSED.]

UNITED STATES CIRCUIT COURT.

EASTERN DISTRICT OF PENNA.

April Sessions, 1884.

No. 15.

AMERICAN BELL TELEPHONE COMPANY ET AL.

v.

CLAY COMMERCIAL TELEPHONE COMPANY ET AL.

APPEAL OF DEFENDANTS TO SUPREME COURT OF U. S.

Filed April 15th, 1886.

WM. W. KER,
FURMAN SHEPPARD,
Atty's for Defendants.

And afterward, to wit, on the 11th day of June, A. D. 1886, the respondents, by their counsel, William W. Ker and Furman Sheppard, Esquires, come into court here and deposit into the Registry thereof the sum of sixteen hundred dollars as security, on appeal to the Supreme Court of the United States.

THE UNITED STATES OF AMERICA, ss.

To the American Bell Telephone Company and The Bell Telephone Company of Philadelphia, GREETING:

You are hereby cited and admonished to be and appear at a Supreme Court of the United States, to be holden at Washington, on the second Monday of October next, pursuant to an appeal filed in the Clerk's office of the Circuit Court of the United States, for the Eastern District of Pennsylvania, in the third circuit therein. The Clay Commercial Telephone Company, John C. Scott, James McMillan, George W. Bratton, Samuel P. Godwin, Henry Clay, John J. Bailey, John Marston, Jr., Thomas C. Else, James McCreighton and Joseph Wright, appellants, and you are appellees, to show cause, if any there be, why the decree rendered against said appellants, as in said appeal mentioned, shall not be corrected, and why speedy justice should not be done to the parties in that behalf. Witness my hand, this 14th day of June, in the year of our Lord one thousand eight hundred and eighty-six.

W. McKENNAN,
Cir. Judge.

Service admitted this 15th day of June, A. D. 1886.

CHARLES HOWSON,
pro Appellee.